Author:
Edward, Scrutton Michael

Title:
The distribution and ecology of recent foraminiferida off the Ebro Delta, Northeastern Spain

VOLUME TWO

CHAPTER 9

CORES

It was originally intended that by taking subsurface samples, information could be gathered on the stratigraphy of recent and subrecent deltaic deposits, particularly in respect of any changes in the foraminiferal fauna. Unfortunately no coring apparatus was available to give cores good, or deep enough for this purpose, but those that were obtained have been examined and their environmental significance determined on the basis of their sedimentary character and their foraminiferal fauna.

A small number of short cores were obtained from the subaerial part of the delta by means of a 'Mackintosh Hand Boring and Prospecting Tool'. The procedure for taking a core using this apparatus is as follows: a thin steel rod, to which a pointed driving head is attached, is driven into the ground by means of a hammer attachment. Further rods can be coupled to those driven into the ground, and the head is driven to the desired depth. The rods are then withdrawn, the driving head removed and a core tube substituted. The apparatus is replaced in the core hole and lowered until the core tube reaches the bottom whereupon further hammering will cause sediment to enter the core tube. The rods are withdrawn once more and the core tube removed and the core extracted from it. Each core has a diameter of 2.5 cm and is just over 15 cm. in length. The maximum depth to which the rods can extend is 15 m.

In practice, this method of coring is far from easy and there are many drawbacks. It is often very difficult to drive a core through sandy sediments and even harder to draw it out; sometimes it took two persons a considerable time to extract the coring apparatus, and one one occasion it was necessary to abandon some rods altogether. The greatest disadvantage arose when the core tube was inserted into the core hole because one could never be certain that it did not scrape sediment from the walls of the hole when it was lowered. Practically no core was taken without some contamination and at worst it was possible for the tube to be driven completely into the side wall and extract sediment from a higher level than the bottom of the hole. Another drawback was that because coring penetrated the water table, the core holes could not be kept open where fluid muddy sediments were encountered. Many coring failures, and eventually loss of equipment during coring, led to the coring programme being abandoned. Nevertheless, a number of short cores were obtained but only those considered to be reasonably free from contamination were accepted for examination. All core sites are plotted in figure 97.

Samples from offshore cores drilled by Shell were kindly supplied by Dr. C. Kruit. 8 samples are from two cores drilled at a site approximately 28 km. southeast of Cabo Tortosa (position: 1° 12'E, 40° 35'N) in water of approximately 86 m. depth, while 5 other samples are from a core drilled farther to the south (0° 52'E, 40° 13'N) at a depth of approximately 84 m. All the samples were treated as described in chapter 6, and the foraminiferids counted in the same way as the dead populations for the Ebro surveys. In addition, about 100 planktonic specimens were picked from each of the samples from the offshore cores and the proportions of each species calculated. Each core sample is described and discussed in the following pages and the details are also listed with the foraminiferal data in Appendix 2c.

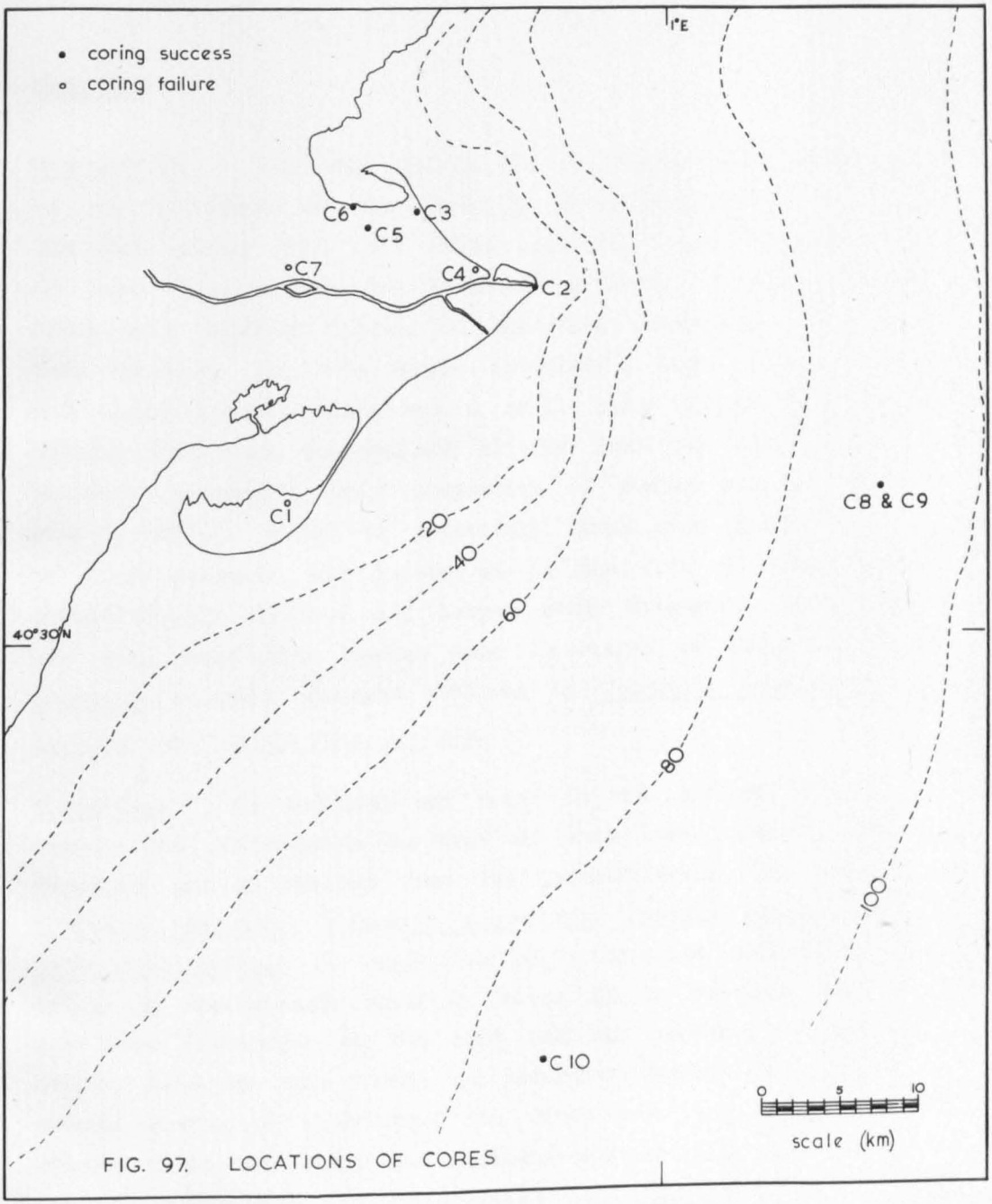


FIG. 97. LOCATIONS OF CORES

Core C 2

Description: This was drilled on the beach about 40 m. south of the lighthouse at Cabo Tortosa. After penetrating the beach sand the core passed into soft muddy sediments which extended down to at least 7 m. A core was taken at a depth of 3 m., but deeper cores were rejected because of excessive contamination by near surface sediment. The core sample revealed a light brown, unlaminated mud. After sieving there was a small sandy residue but it is thought that this was derived chiefly from the beach sands. The sediment contains a small proportion of shelly material together with a certain amount of relatively large mica flakes and fragments of plant material. The latter is in the form of both finely divided organic material and larger woody fragments. Foraminiferids are rare, only four species were discovered of which Elphidium oceanense is most abundant followed by Jadammina macrescens, Ammonia beccarii and Trochammina inflata.

Discussion: No sediment was found in the present deltaic environments that corresponds to that of this core. However, some information can be derived from the foraminiferids. The presence of Elphidium oceanense, Jadammina macrescens, Ammonia beccarii and Trochammina inflata is suggestive of a brackish environment such as exists in the present brackish lakes. It is possible that when the river discharged to the east and the southern channel was active, Isla de Buda formed an interdistributary bay type of environment. Floods of water from the river over the levees would deposit silts and clays and periodic contact with the sea would maintain a brackish, but fluctuating salinity. A considerable thickness of interdistributary deposits probably accumulated as the delta advanced eastwards.

Core C 3

Description: This was positioned at the eastern end of the northern abandoned river course, behind the beach about 400 m from the sea. After passing through 1 m. of surface sand the core passed into soft muds which continued to a depth of at least 5 m. Sample C 3/1 was taken at 3 m. depth and C 3/2 at 4½ m. Both produced the same sediment, a grey - green clay with occasional organic fragments. In the float there are a few charophytes while foraminiferids are fairly abundant. Protelphidium anglicum is dominant in both samples followed by Ammonia beccarii and Elphidium oceanense, but in C 3/2 there are a few individuals of Asterigerinata sp. and E. advenum.

Discussion: These sediments are identical with those exposed at the surface a short distance from the core site that have been recognized as typical abandoned course deposits. Abundant woody fragments are typical of sediments associated with the present river channel; charophytes have similar affinities. The predominance of Protelphidium anglicum in the fauna is typical of a standing body of nearly freshwater such as occurs at present in Encanizada. This would tie in well with the picture of the abandoned channel becoming a body of standing freshwater. There was probably occasional incursion or percolation of seawater into the channel to make the water slightly brackish, and this would account for the presence of brackish species like A. beccarii and E. oceanense. The presence of nearshore species in C 3/2 is attributable to contamination from the surface sands which have been blown back from the beaches.

Core C 5

Description: This core was taken farther inland on the same former river course as core C 3; two samples were obtained, C 5/1

at 3 m. depth and C 5/2 at 6 m.

C 5/1 is a grey mud and only a small proportion of it remains after sieving. The residue is chiefly sand with relatively large flakes of mica and abundant blackened woody fragments. Foraminiferids are rare but a few tests of Protelphidium anglicum were found.

C 5/2 is a muddy sand; the light brown mud fraction is lost with sieving and leaves a relatively large residue of medium grained sand. Again, woody debris and mica flakes are common but the sample is barren of foraminiferids.

Discussion: C 5/1 is virtually the same as the other abandoned channel deposits and probably has a similar origin. The higher content of woody material is not unusual since it is characteristic of many river deposits, while the small number of foraminiferids is probably attributable to increased distance from the sea. Although P. anglicum can tolerate freshwater conditions it does not penetrate far inland (Murray 1961), and it is probably dying out towards this end of the old river channel.

C 5/2 is a different sediment altogether and nothing comparable was discovered on the present delta. However, it is likely that it is also an abandoned channel deposit, probably at the base of total thickness of these deposits. Kolb and Van Lopik (1966), in discussing abandoned channel deposits on the Mississippi delta, demonstrated that sediments were coarser near the point of diversion of the river. They showed that there was a wedge of sandy sediments at the base of the abandoned channel deposits, thickest near the point of diversion and narrowing downstream. It is possible that C 5/2 represents this type of deposit.

Core C 6

Description: The site of this core is the southern edge of Fondeadero del Fangal (the northern lagoon), about 50 m. from the edge of the water. C 6/1 was taken at 2½ m. depth and C 6/2 at 6 m. The sediments are not uniform throughout this depth; at approximately 3 m. and 4 m. the core passed through harder bands, probably sands. The sediment from both core samples is a dark coloured muddy sand with a small proportion of shelly material including some whole bivalves. Foraminiferids are very abundant and each sample yielded 15 or more species in a count of 250 individuals. In each case the fauna is dominated by Ammonia beccarii which has around 50 % relative abundance.

Discussion: The sediments from these core samples are very similar to the surface sediments of the northern lagoon and the foraminiferal fauna also suggests a lagoonal origin. Comparison of the faunas with the dead populations of stations S/18 and S/20 in the northern lagoon produces similarity indices between 42 and 60 %. The main differences are due to the increased proportions of marginal species such as Protelphidium anglicum, Elphidium oceanense and Ammonia beccarii in the core faunas, as opposed to a high miliolid content in the present central lagoon dead populations. Lagoonal sediments have accumulated to form a thickness of at least 6 m. at the core site. It is likely that the lagoon coastline has not been static but has fluctuated slightly; however, the core faunas suggest marginal lagoon conditions so it is unlikely that the lagoon extended much farther to the south than it does at present. The fact that there are two 'hard' bands of sediment at 3 and 4 m. depth also indicates fluctuating sedimentary conditions.

Core C 8

Description: This core consists of five samples from various levels of a continuous core drilled offshore southeast of Cabo Tortosa.

C 8/1 is a section from 0.25 - 0.4 m. below the top of the core and is an unlaminated brown clay. Shelly material is reasonably abundant and includes bivalves, gastropods, echinoid spines and a diverse foraminiferal fauna. The latter is dominated by Elphidium advenum followed by just less than 10% each of miliolids, Valvulineria complanata and Gyroidina c.f. G. umbonata.

C 8/2 is from 2.25 m. and is a similar unlaminated brown clay but with a relatively higher shell content, much of which is broken. Foraminiferal, mollusc and echinoid remains are common and there are many whole, small gastropods and bivalves, chiefly of the species Corbula gibba, Cardium edule and Turritella communis. The foraminiferal fauna is again fairly diverse, but this time Elphidium crispum is most abundant followed by several species with around 5% relative abundance. Many of the tests, particularly of E. crispum, are blackened.

C 8/3 is from 2.25 m. to 2.43 m. and is once more an unlaminated clay with a small shell content. Foraminiferids continue to be abundant and the fauna is very similar to C 8/2 (64% SI) although E. advenum is most abundant.

C 8/4 from 4.25 m. is a very fine brown clay with very little shelly material. The residue after sieving is very small and consists only of foraminiferids and fine organic debris. However, foraminiferids are relatively less abundant than in previous samples and the fauna is less diverse. The most abundant species are Elphidium lidoense, Cassidulina laevigata, Nonionella opima and

Elphidium sp. 1.

C 8/5 is from 4.25 m. to 4.43 m. depth below the top of the core and is a brown clay with a small sand content and some shelly material. Foraminiferids are more abundant than in C 8/4 but this time Ammonia beccarii is most abundant closely followed by E. advenum.

Discussion: All the samples from this core have sediments that are fairly similar and all the foraminiferal faunas have a similarity index with each other of greater than 50%, and so the samples can be considered collectively.

The position of this core is probably close to the seaward limit of deltaic sediments, and the clays are typical of delta bottomset beds or 'offshore clays'. The foraminiferal fauna is unusual in that it contains a mixture of both shallow and deep water species. The latter are represented by species such as Textularia sp., Bulimina sp. 2, Gyroidina c.f. G. umbonata and Globocassidulina sp. which are not recorded in any samples from the delta surveys. In addition, there are species that occur commonly around the delta but are most abundant in deeper water so that they would be expected to occur at depths outside the range of the surveys. Examples of these are Nonionella opima, Bulimina aculeata, Valvulineria complanata, Cassidulina laevigata Epistominella vitrea and Melonis pompilioides.

There are also a number of shallow water species that are present in a depth (86 m.) well below the maximum depth at which they are found living. Examples are Nonion depressulus, N. laevigatum, Ammonia beccarii, Elphidium advenum, E. crispum, E. lidoense, Eponides granulata and many miliolids, and there are even some records of Bolivina pseudoplicata and Patellina corrugata which are only found

living in the Ebro lagoons. It is estimated that between 25 and 50% of the total fauna from each sample is composed of shallow water forms, the rest being composed of indigenous or planktonic species.

Having established the shallow water nature of a great proportion of the fauna it is necessary to consider the method by which they came to be present in such a depth. Displacement of shallow water sediments into deeper water giving rise to an anomalous foraminiferal fauna has been described from several parts of the world but it does not appear that this is the case here. The core sediments are exclusively clays with virtually no residue after sieving apart from shelly material. This contrasts with most nearshore sediments of the delta which usually have a high proportion of sand. In addition, the very fact that the fauna is mixed suggests that both indigenous and shallow water forms were accumulating at the same time. If a body of sediment had been displaced from shallow water it would contain only shallow water species.

Therefore it is most likely that the species in question have been reworked and transported from shallow water into deeper water by some means not involving the sediments. However, there is no evidence for this continuing at present on the scale involved in the cores; the dead populations from the deeper water stations off the delta have no unusual proportions of forms derived from shallow water. It was observed that in cores C 8 and C 9 the relative abundance of derived shallow forms decreases towards the top of the cores from approximately 50 to 22%. It is possible that many of the shallow forms are derived from the reworking of old delta deposits. As the original delta apex (of growth phase 1) was abandoned and subject to vigorous erosion, sediments were eroded and foraminiferids reworked. Initially the rate of erosion was very rapid but it slowed as the coastline was 'flattened' and it is

thought that the large number of shallow water forms is related to the cutting back of this old delta apex. At present, the erosion of this part of the coastline has slowed considerably and probably explains the negligible proportion of shallow water forms in the present deep water dead populations; surface sediments at the core site would probably reveal the same features.

Core C 9

This was drilled in approximately the same position as core C 8 and three samples were available from the following levels:

C 9/1 - 0.4 - 0.58 m.; C 9/2 - 2.4 - 2.58 m.; C 9/3 - 3.4 m.

All three samples are similar to those of C 8 and are light brown unlaminated clays with a small amount of shelly material including foraminiferids, bivalves, gastropods and echinoid spines.

The foraminiferal fauna of C 9/1 is dominated by Epistominella vitrea followed by Elphidium advenum and Textularia calva while in C 9/2 E. lidoense and Valvulineria complanata are most abundant. C 9/3 is very similar to C 9/2 (72% SI) with the same two species dominant.

As with C 8 there is a mixture of shallow and deeper water species, and although there are slight differences in the component species and their relative abundance, it is thought that the origin of the fauna is the same as for C 8.

Core C 10

Description: This core was taken approximately 55 km. south-south-west of C 8 and C 9 and is again near or just outside the estimated seaward limit of deltaic sediments. Five samples were available from the following levels:

C 10/1 0.22 m.
C 10/2 1.22 m.
C 10/3 1.22 - 1.4 m.
C 10/4 2.2 m.
C 10/5 2.2 - 2.4 m.

C 10/1 is a light brown mud with shelly material including small gastropods and whole valves of Cardium. Foraminiferids are abundant but the fauna is not diverse and is dominated by more than 80% of Ammonia beccarii. C 10/2 is almost identical except that A. beccarii has a lower relative abundance. C 10/3 is a laminated clay with a smaller shelly fraction but the foraminiferal fauna is similar to the preceding ones. C 10/4 and C 10/5 are again unlaminated brown clays but although A. beccarii is still very abundant in the foraminiferal faunas, they are both dominated by miliolids.

Discussion: The foraminiferal fauna of C 10 is unusual in that, apart from an occasional planktonic specimen, no species is indigenous to the depth of water in which the core was drilled. In fact the species and their relative abundance are typical of an Ebro lagoon fauna; comparisons of the faunas with the dead populations of the southern lagoon gave similarity indices between 40 and 67%. The bivalve Cardium is also typical of the lagoon. However, the core sediments are not consistent with those in much of the southern lagoon at present; the latter usually have a sand fraction more than 10% of the total sediment. More muddy sediments occur nearer the lagoon entrance and it must be assumed that this is the situation of origin. There is no other area along the coast south of the delta that would have similar sedimentary and faunal characteristics.

It appears likely that the whole length of core C 10, a body of sediment of at least 2.4 m. thickness, has been trans-

ported from the southern lagoon or a former delta lagoon with a similar fauna. The mechanism of this transport or displacement is not known. Various authors have argued for or against turbidity current transport while other suggestions involve submarine slumping or funneling of sediment through submarine canyons. No graded bedding or other sedimentary structures were observed in the core samples to give some indication of their mode of displacement. Displaced sediments have often been observed associated with submarine relief and it is possible that the influence of the delta means that the submarine slope along this part of the coast is slightly steeper than in other areas. This will certainly aid, and perhaps even initiate, transport of sediments from shallow to deep water. Displaced sediments have been reported from several localities in the Mediterranean, and Parker (1958) reported displacement of shallow water benthic foraminiferids into deeper water in 7 surface sediment samples from the eastern Mediterranean. Menard et al. (1965) noted movements of large quantities of sediments seawards over the Rhône delta fan.

Phleger (1951) recognized displaced shallow water sands in deep water off the Californian coast. He distinguished mixed and unmixed faunas which he considered were of turbidity current origin. He also recorded (1955) abundant shallow water forms in depths around 1300 m. from cores off the Mississippi delta and again presumed that turbidity currents were responsible for the displacement.

Triangular plot

The core samples have been plotted on the triangular diagram of the foraminiferid suborders for the dead populations for environmental comparison (figure 98). Cores C 2 and C 3 each have 100%

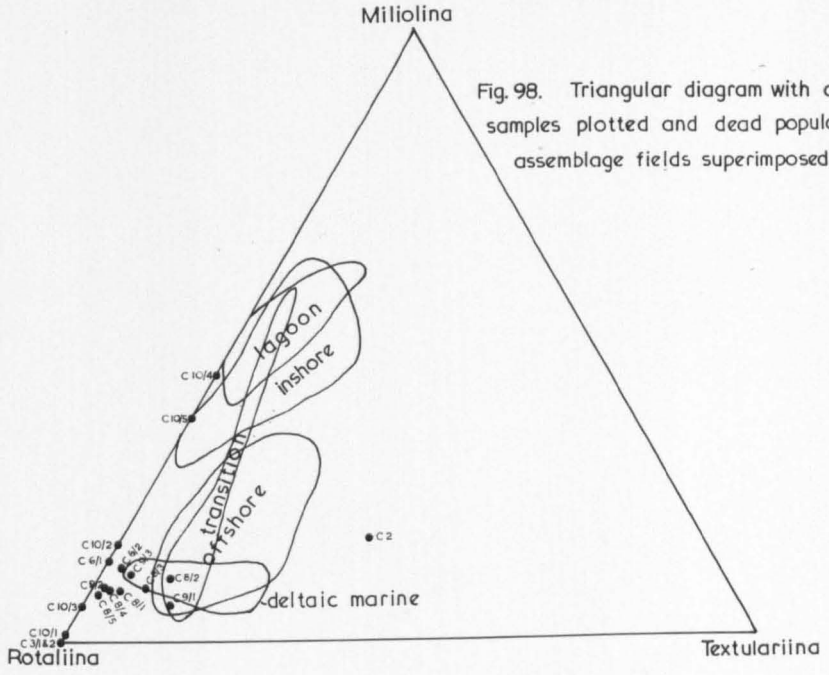


Fig. 98. Triangular diagram with core samples plotted and dead population assemblage fields superimposed.

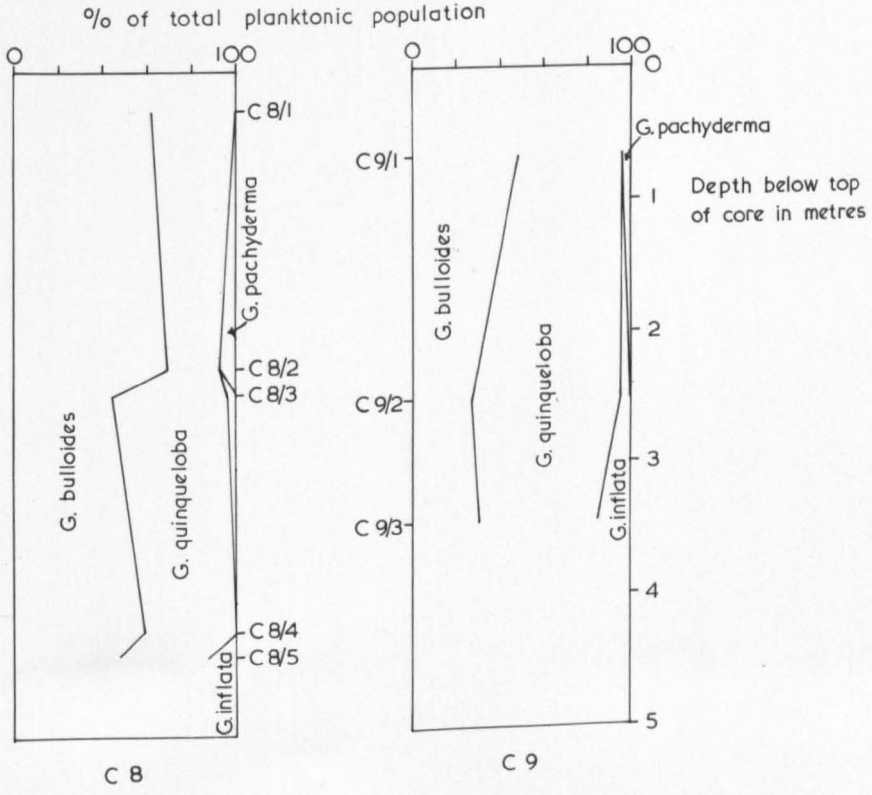


Fig. 99. Proportions of planktonic species in cores C8 and C9

Rotaliina, much the same as populations from Encanizada. Samples from C 6 plot well below the lagoon field and the relatively low proportion of Miliolina has been explained by their representing marginal lagoon conditions. The dead populations on which the lagoon field is based are only from the central lagoon area.

Samples from C 8 and C 9 plot within or just outside the offshore and deltaic marine fields. There is a relatively low proportion of Textulariina in these deeper samples and, although there is a large proportion of derived 'inshore' forms, there are relatively few miliolids so the samples do not plot near the inshore assemblage field. The samples from C 10 have no Textulariina at all and C 10/1, C 10/2 and C 10/3 also have low percentages of Miliolina. These are probably again marginal lagoon sediments like C 6, while C 10/4 and C 10/5 plot much closer to the lagoon field and probably represent populations very close to those existing in the central parts of the lagoon at present.

Planktonic species

Planktonic species are fairly common in the foraminiferal faunas of the offshore core samples from C 8 and C 9, but not from C 10 as this represents lagoonal conditions. Four planktonic species are recognized: Globigerina bulloides, G. inflata, G. quinqueloba and G. pachyderma and the proportions of each of these are illustrated in figure 99.

In core C 8 G. bulloides is dominant throughout with G. quinqueloba next abundant and with smaller numbers of G. inflata and G. pachyderma. The last two are not found together; G. pachyderma occurs near the top of the core while G. inflata is most abundant near the base. In C 9 G. bulloides is most abundant at the top

of the core but lower down G. quinqueloba is most abundant; again G. pachyderma occurs near the top and G quinqueloba near the base of the core.

In the Ebro dead populations the majority of planktonic species were also G. bulloides, G. quinqueloba and G. inflata suggesting that there has been little change in the planktonic fauna in recent times. Isolated specimens of Orbulina universa, Globigerinoides rubra and Globorotalia scitula were also observed. All the above species have been commonly recorded from various parts of the Mediterranean in surface sediment samples, plankton tows and submarine cores (e.g. Erikkson 1961).

Bé and Hamlin (1967) note that G. bulloides, G. quinqueloba and G. inflata are all 'subarctic' species most abundant in temperatures ranging from 11 - 15°, while G. inflata is a 'transitional' species most abundant between 13 and 17° C. Very little can be determined from the succession of planktonic foraminiferids in the cores. The slightly increased proportions of G. inflata deeper than approximately 2½ m. might indicate slightly warmer conditions but the fauna is predominantly 'subarctic'. The optimum temperatures for the most abundant planktonic species are approximately the same as the winter minimum temperatures for the western Mediterranean. The fauna is very similar to that in samples from the Western Approaches to the English Channel and is possibly a 'relict' fauna. The cold water species may have migrated into the Mediterranean during a Pleistocene glacial period when the sea temperatures were much lower than at present and they have persisted since then despite a temperature increase.

CHAPTER 10

ORIGINS OF THE EBRO FAUNA

Introduction

The origins of the Mediterranean foraminiferal fauna is closely tied up with the history and development of the Mediterranean Sea itself. Geographical, climatic and oceanographic changes, particularly through the later part of the Tertiary, have had a profound effect on the development and evolution of all animal populations. For this reason it is considered worthwhile tracing the history of the Mediterranean to review events that were of importance from a biological point of view. Very few modern species extend in time beyond the Miocene and so it is proposed to pick up the history of the Mediterranean from that time. Published works have been studied and many Tertiary and Recent foraminiferid slides in the Protozoa section of the British Museum (Natural History) were examined. In addition many samples from the Mediterranean area were collected by, or on behalf of the author for comparison with the Ebro delta fauna. A list of these can be found in Appendix 3.

The present shape of the Mediterranean was only attained during the Quaternary following the Alpine earth movements that greatly affected the southern European area. For most of the Tertiary, what is now recognized as the Mediterranean was only a part of a larger sea, named Tethys, that covered most of southern Europe,

the Black Sea, the Caspian Sea, and stretched through the Middle East to connect with the Indo - Pacific region. Tethys is thought to have been in existence since the Lower Palaeozoic and throughout its history it is regarded as a warm water sea. This is important from a faunal point of view since it means that indigenous Tethyan organisms are adapted to warmer water, and that if colder water species are encountered at any stage then they must have originated outside Tethys.

To date, the majority of published work on the origins and evolution of Mediterranean faunas have been concerned with animal groups other than the Foraminiferida, although there is a small amount of information concerning the latter, chiefly on planktonic forms. Most work has been undertaken on molluscs, but general conclusions about their migrations etc. will probably hold true for foraminiferids as well. To illustrate the validity of this assumption, the beginning of the Pleistocene has long been recognized by the relatively sudden influx of cold water molluscs, such as Cyprina atlantica. Emiliani et al. (1961) studied a section at La Castella, southern Italy, and discovered that the molluscan changes over the Plio/Pleistocene boundary were paralleled by changes in the foraminiferal fauna. Cold species such as Hyalinea balthica appear suddenly and confirm that benthic foraminiferids also respond quite rapidly to environmental changes.

Mechanisms of foraminiferal migration

In the following pages various migrations and foraminiferal changes are suggested and it is perhaps worthwhile first of all to consider the methods by which these movements are carried out.

It is well known that foraminiferids are capable of inherent movement by means of their pseudopodia, but this is very slow

and can probably be disregarded as a means of migration over large distances. The obvious method of movement of benthic foraminiferids over long distances is by means of transport by bottom currents. The majority of foraminiferids, particularly juvenile specimens, are very small and easily transported by strong littoral currents. This sort of movement is probably going on more or less continually along all coastlines at present but there must be certain controls on movements or all species would be cosmopolitan in distribution. The strength and the direction of the currents are important but the crucial factor is the environment in which the transported foraminiferids are eventually deposited. If this is favourable then the species will flourish and produce new colonies, otherwise they will die off, or at best, only survive for a short period. Intense storm activity may have important distribution significance. Nearshore bottom sediments may become disturbed and foraminiferids taken up into suspension and transported certain distances before being deposited. Phleger (1951) reported the presence of living benthic foraminiferids in plankton tows from the northwest Gulf of Mexico, while Murray (1965) found empty tests of benthic species in plankton samples from the English Channel following a prolonged period of storms.

Although transport parallel to coastlines is relatively easily explained, there are similarities in both modern and fossil benthic faunas between continents that are more difficult to account for. It is probable that migration occured across the ocean in some way, but obviously movement along the sea floor is impossible because of the great depths and distances involved. The most plausible theory to explain trans - oceanic migration is that involving 'rafting' as first proposed by Vaughan (1933). It has been observed that during severe storms or hurricanes in the Caribbean area large masses of weed often become detached from the sea floor and are subsequently caught up in the current system to drift towards

Europe with the Gulf Stream. These masses of weed have a variety of benthic animals trapped within them, including benthic foraminiferids. The animals are transported across the ocean on the 'raft' and eventually produce colonies on the opposite side of the ocean provided that they are deposited in a suitable environment.

Development of the Mediterranean

In the Eocene and Oligocene, Tethys stretched from southern Europe through the Middle East to the Indo - Pacific region, and Ekman (1953) says that at this time it was a fairly uniform zoogeographical province. On the other hand, Adams (1967) argues that the Tethyan fauna of larger foraminiferids was distinct and that there were periodic influxes of new species from the Indo - Pacific and from America across the Atlantic. Some authors have proposed that migrations across the Atlantic took place the other way round, i.e. from east to west, but Barraclough-Fell (1967), in a study of Atlantic current systems through the Cretaceous and Tertiary, notes that the current system has been much the same as at present well back into the Tertiary and it is very unlikely that any east to west migrations could have occurred by the methods suggested.

Peres (1967), dealing with molluscs, states that the fauna of this early period was largely dominated by animals of a true tropical character that had migrated into Tethys from the Indo - Pacific region. He named this influx the 'Palaeomediterranean' element. He adds that there were some indigenous elements in the fauna, and the fact that Tethys was a 'closed' sea with only very restricted connections with other seas meant that there were ideal conditions for evolution of species in isolated marine areas. Peres also notes that later evolution in situ allowed some endemic Mediterranean

species to be derived from the Palaeomediterreanean forms.

Miocene: In the Miocene, Ekman claims that many of the tropical species died out because of a deterioration in the climate, but Adams (1967) says that, as far as foraminiferids are concerned, the Lower Miocene marked a world - wide change in the populations of larger foraminiferids and it was unlikely that this change had anything to do with climatic deterioration.

Important changes took place in Tethys during the Miocene, some as a result of the Alpine orogeny. Communication with the Indo - Pacific gradually became restricted and was probably terminated by the Middle Miocene. This left a vast enclosed sea extending from the Vienna Basin eastwards to the Caspian; this is named 'Paratethys' by Peres (1967), and he adds that it had periodic connection with the rest of Tethys across the Balkan Peninsula and Turkey. At the end of the Middle Miocene, communication with the Atlantic, which previously had been by two wide arms of water through what is now southern Spain, was reduced. These two connections, the Betic and Rif Straits, were gradually elevated, the Betic Strait first followed shortly afterwards by the Rif Strait. The latter however, maintained restricted contact with the Atlantic until the Upper Miocene, but was eventually closed by a great marine regression. A period of isolation from the Atlantic followed.

Ruggieri (1967) states that towards the end of the Miocene an evaporitic situation arose in the western Mediterranean with gypsum and salt formation being quite widespread. As the connection with the Atlantic was lost and the sea regressed, the western Mediterranean became transformed into a series of lagoons which either dried up completely or became gradually desalinified.

These events have considerable significance from a biological point of view. The closing of the connection with the Indo -

Pacific meant that no more tropical species could migrate into Tethys and the Palaeomediterranean element gradually became reduced. With the closure of the Atlantic connection, Tethys became a completely enclosed sea, ideally suited for evolution of species in geographical isolation. In addition, the changes in the western Mediterranean resulted in the wiping out of marine animals there and Ruggieri notes that the basins of reduced salinity were characterized chiefly by gastropods of oligohaline, warm water facies, mainly of the genus Melanopsis. This Melanopsis fauna appears in rocks in North Africa, Catalonia, Sicily and various parts of Italy. It is unlikely that all marine organisms of this time were lost; many may have survived in the marine conditions that persisted in the eastern Mediterranean.

Pliocene: Meanwhile, tectonic deformation of the Betic - Rif massif continued until Atlantic waters once again poured into Tethys through what is now the Straits of Gibraltar. Marine conditions were quickly established in the western Mediterranean and this transgression is regarded as the beginning of the Pliocene. It is important because it brought in a new influx of species that, during the isolation of Tethys, had been living just outside in the Atlantic. Ruggieri says that in areas characterized by a Melanopsis fauna, the transgression is manifest by a sudden change of fauna, with marine, predominantly planktonic, species taking the place of oligohaline ones. Subsequently a benthic fauna was also introduced.

Climatic cooling is generally advocated during the Pliocene and Peres says that this caused the Palaeomediterranean element to diminish further as temperatures became too cold for animals that were basically tropical in character. Adams (1967) notes that larger peneroplids, although generally cosmopolitan in distribution, were rare in the Tethyan region in the late Tertiary probably because of the lower temperatures. Ruggieri considers that, with a few

exceptions, animals of a true tropical character did not extend beyond the lower Pliocene. A further regression occured in the Upper Pliocene but at this stage the animals were still basically warm water forms.

Pleistocene: The beginning of the Pleistocene saw a marked change in conditions. The Plio/Pleistocene boundary is generally taken as coinciding with the sudden appearance of cold water molluscs which in turn reflect the deterioration of the climate. Emiliani et al. (1961) recorded the appearance of cold water molluscs at the section near La Castella, southern Italy, and also recorded the incoming of cold water benthic foraminiferids such as Hyalinea balthica, Asterigerinata mamilla, Buccella frigidus, Nonionella turgida, Cassidulina laevigata and Trifarina angulosa. Selli (1967) adds that Nonion germanicum and Patellina corrugata were also cold immigrants at this time. By isotopic measurements, Emiliani et al. determined that the temperature fall over the Plio/Pleistocene was of the order of 5°C. Absolute temperature minima in the early Pleistocene, although several degrees lower than the present day, they considered were too high to represent truly glacial conditions and they suggested that the temperature level might reflect the mountain glaciations that preceded the major glaciations. Selli (1967) calculated temperatures at this time to have been about 20° down to about 50 m. water depth and 14 - 15° "a few hundred metres below".

Peres (1967) considers that the widespread cooling during the Pleistocene had two main effects on the fauna of the time:

1. The influx of an Atlantic fauna which now consitutes the main faunal element in the Mediterranean.
2. The presence in shallow water of cold - loving species which in the warmer Pliocene period were restricted to deep water bottoms where the temperatures were slightly lower.

Throughout the Pleistocene there were many climatic fluctuations associated with glacial and interglacial periods and these had important effects on the fauna. Glacial periods probably resulted in changes in the oceanography of the Mediterranean, and the theory of 'Inversion of currents' as described by Mars (1963) will be outlined.

In a typical interglacial period, as at present, the Mediterranean has a warm, semi - arid climate with low precipitation and runoff from land areas. The warm temperatures result in high evaporation from the surface waters of the sea which runoff cannot supplement. This creates a deficiency in the water balance and is compensated by an influx of water from the Atlantic. An easterly current enters the Mediterranean and flows over the Mediterranean water since the latter has been made more dense by evaporation. Eventually evaporation acts on the Atlantic water as well increasing its density until it is able to mix freely with the Mediterranean waters. Balancing the inflowing surface current is a counter flow of denser Mediterranean water which goes out through the Straits of Gibraltar as a bottom current.

In a typical glacial period accumulation of ice causes a eustatic regression which reduces sea level. The arid zone moves farther south and the Mediterranean climate becomes humid, temperate and cool. Zeuner (1959) said that the glacial sheets over Europe during these periods would create high atmospheric pressure above them which would compel the many barometric depressions coming in from the Atlantic to be deviated southwards into the Mediterranean region. The result is increased precipitation and runoff which reverses the water balance so that a surface current of less dense Mediterranean water would flow out into the Atlantic with a corresponding bottom counter current.

The inversion of the current system was probably a very gradual process and there would be a period during the change-over when currents were very much reduced allowing stagnant conditions to develop in some parts of the Mediterranean. Olausson (1961) examined some Pleistocene cores from the Mediterranean and observed that some of the sediments were deposited under stagnant conditions, probably due to higher than normal contribution of river effluent from the Black Sea. Van Straaten (1966) also noticed indications of stagnant conditions in early Pleistocene cores from the southeast Adriatic.

The significance of the inversion of currents from a faunal viewpoint is that, during glacials, the influx of colder water from the Atlantic would favour the introduction and maintenance of a boreal fauna at deeper levels in the Mediterranean. Peres (1967) proposes that the hypothesis accounts not only for immigration of cold water species during glacials, but also of warmer faunas during the interglacials. He draws up a table (Table 11) to show the percentage representation of the Mediterranean species of certain animal groups in areas outside the Mediterranean. This illustrates that the dominant faunal elements are endemic and North Atlantic, while other species are cosmopolitan, Senegalian or Circum - tropical in origin, with fewer numbers of Palaeomediterranean and Central Atlantic forms.

Origins of the Ebro foraminiferids

The Ebro delta fauna falls into the pattern outlined by Peres for other animal groups in that the species have a variety of affinities. Many of the species have been living in the Mediterranean for some time, and as long ago as 1860 Parker and Jones recognized that "A large number of Foraminifera obtained from the Tertiary of Tuscany, Piedmont and other countries bordering

TABLE 11

Group	Hydroids	Decapoda Reptantia	Echinoderm -ata	Ascidians
Total number of species	192	129	107	132
Northern Atlantic	41.6	56.6	50.0	31.8
Senegalian	0	17.9	14.0	2.2
Central Atlantic	3.6	2.3	4.6	1.7
Circum - tropical	10.0	2.3	0.9	4.5
Cosmopolitan	17.2	4.6	2.8	5.3
Indo - Pacific	0	3.0	0.9	3.2
Endemic	27.1	13.2	26.1	50.4

The extra - Mediterranean distribution (%) of Mediterranean species. (After Peres, 1967).

the Mediterranean bear a close relation to the Recent Foraminifera of the same area". Without a good Tertiary sample coverage it is difficult to be certain about the first appearance of a species, and so conclusions drawn are somewhat speculative. The following species in the Ebro fauna are probably indigenous to the Mediterranean, or at least, have not yet been recorded from elswhere:

Asterigerinata sp. (?)
Elphidium c.f. E. flexuosum
E. lidoense
Nonion leavigatum
Eponides granulata
Fursenkoina schreibersiana
Valvulineria complanata
Uvigerina sp. (?)
Rectuvigerina c.f. R. compressa
Delosina complexa
Quinqueloculina depressa
Q. schlumbergeri
Q. longirostra
Triloculina dubia
T. rotunda

Several of these species have been recorded in Miocene rocks, including R. c.f. R. compressa, E. c.f. E. flexuosum and V. complanata, and must be well adapted to have withstood the climatic changes through the later part of the Tertiary. Endemic species form a relatively high proportion of the total fauna and Peres (1967) says that a high rate of endemism is to be expected in the Mediterranean. He says that endemism is to a large extent influenced by reproduction within a confined space, so if topographically distinct populations of a species mix during its reproductive period, the species preserves its unity, whereas if populations prosper independ-

ently, morphological differences can fairly quickly be established between them by the development of mutants. This would particularly apply to less mobile animals and Peres observes that the percentage of endemics increases with decreasing mobility of the animal groups.

The isolation of the Mediterranean during the Miocene was probably a very suitable period for the development of indigenous species and some of those listed previously may well have originated at this time. Generally, indigenous Mediterranean foraminiferids are adapted to warmer water and many probably died off during the Pliocene and Pleistocene when the water temperatures became lowered. However, the eastern corner of the Mediterranean was less affected by the temperature changes and many species may have survived by withdrawing to this region. Parker (1958) notes that the majority of eastern Mediterranean foraminiferids are indigenous and many are prevented migrating farther west by the lower water temperatures there.

Apart from the indigenous species, other species adapted to warmer water were able to enter the Mediterranean by two different routes. Before the connection was severed, many forms migrated in from the Indo - Pacific region, while other species migrated along the northwest coast of Africa when the temperatures were warmer. Few, if any, Palaemediterranean species remain in the Ebro delta area; most probably died out during the Pleistocene. It is possible that a few species may still remain in the eastern Mediterranean, but Said (1950) and Reiss et al. (1961) have observed that the Red Sea fauna, which is definitely Indo - Pacific in its affinities, bears little resemblance to the fauna of the eastern Mediterranean. Said, however, noticed great similarities of the Red Sea fauna with a Pliocene fauna of the Isle of Rhodes. Reusella aculeata is known in the Red Sea and the Pacific, and it is possible that it has Indo - Pacific origins.

Migration of tropical or sub - tropical (Senegalian) species along the western and northern coasts of Africa into the Mediterranean is advocated by Peres for warmer periods, both in the Pleistocene and earlier. No species of foraminiferid with such affinities is found in the present Ebro fauna, but along this part of the Spanish coast there are three commonly recognised Pleistocene raised beach levels, the middle one of which (6 - 8 m.) contains shells of the mollusc Strombus bubonius. This is common today in warmer waters off the coast of Senegal and demonstrates that at some time in the Pleistocene temperatures were warm enough in the Ebro area to support a sub - tropical fauna. Foraminiferal faunas examined from the North African coast bear very little resemblance to those from the northern coastline of the Mediterranean. The southern coastline of the Mediterranean is probably least affected by temperature changes and would be able to maintain a warmer water fauna at most times. Even if a cooler water fauna did become established, warmer water species would soon take over again by migrating along the coastline of Africa when the temperatures rose once more.

Many of the Ebro species are cosmopolitan in distribution with records from many parts of the world. It is very difficult to ascertain the origins of such species. They include:

Ammonia beccarii
Elphidium advenum
E. crispum
Quinqueloculina seminulum
Saccammina difflugiformis

Several species have 'Central Atlantic' affinities, i.e. they are also common along the eastern seaboard of North America and in the Caribbean area. As the current system in the Atlantic has operated from west to east throughout the Tertiary, it is most

likely that these species originated on the western side of the ocean. The Gulf of Mexico is a suitable 'enclosed' sea where many species might have evolved. None of these species is encountered in the Mediterranean Tertiary and it seems that they have migrated across the Atlantic relatively recently. The species include:

Brizalina striatula
'Discorbis' bulbosa
Epistominella vitrea
Hopkinsina pacifica var. atlantica
Nonion c.f. N. matagordanum
Nonionella atlantica
Nonionella opima
Saccammina comprima
Textularia calva
Trochammina c.f. T. advena
T. lobata

The dominant element in the Ebro fauna is a cool water one. Many of the following species are commonly found along the coasts of Northern Europe:

Asterigerinata mamilla
Bolivina pseudoplicata
Brizalina psedopunctata
Brizalina spathula
Bulimina elongata
B. aculeata
B. marginata
Buliminella elegantissima
Cassidulina laevigata
Clavulina obscura
Eggerella scabra
Elphidium oceanense

Elphidium incertum
E. selseyensis
Gavelinopsis praegeri
Haplophragmoides canariensis
Melonis pompilioides
Nonion depressulus
N. c.f. N. germanicum
Patellina corrugata
Protelphidium anglicum
Reophax scorpiurus
R. scottii
R. subfusiformis
R. c.f. R. fusiformis
Rosalina c.f. R. valvulata
Trifarina angulosa
Triloculina sp. (?)

These species were able to migrate into the Mediterranean when the temperature was lowered in the Pleistocene. As temperatures became progressively lower they were able to spread farther and farther south along the Atlantic coast of Europe until they finally rounded the Iberian peninsula. They tended to migrate more along the northern Mediterranean coast since temperatures rarely became low enough for them to colonize the southern coastline. This is confirmed by the presence of few cool water, North Atlantic forms in the modern faunas examined from the North African coast. On the other hand, the northwest Mediterranean coast, the Costa Brava, the Riviera coast and the northern part of the Adriatic all have high proportions of North Atlantic species.

The time of arrival of each of the cool water species in the Mediterranean is impossible to fix and it is possible that with successive glacial and interglacial periods they migrated

backwards and forwards into the Mediterranean. The distance of penetration of the cool water species into the Mediterranean would depend on just how low the temperatures became and the length of time for which they were maintained. Van Straaten (1966), interpreting molluscan assemblages in cores from the southeastern Adriatic, suggested that temperatures at some stages in the Pleistocene became as low as those now prevailing around the Faröe Islands. Emiliani (1955) calculated that temperatures during the Middle Würm glacial were approximately 5 - 7°C lower than the present Mediterranean temperatures. This would render them very similar to those around the British Isles at present.

The present distribution of the cool water species present in the Ebro delta fauna reveals some interesting information. Figure 100 shows the percentage representation of these species in other parts of Europe. It would be expected that the cool water forms would extend from the Ebro delta around the Iberian Peninsula and along the European Atlantic coastline to north of the British Isles. Figure 100 demonstrates that this is not the case. The Spanish and French Atlantic coasts have faunas containing few of the Ebro cool water species, whereas around the British Isles, particularly in the English Channel area, there is a much greater representation. Todd (1958) also observed marked similarities between the foraminiferal fauna of the Western Mediterranean and that of the British Isles area. An explanation for this is proposed.

As temperatures became lowered during glacial periods, cool water foraminiferids living around the British Isles were able to migrate progressively southwards along the nearshore zone until they were able to enter the Mediterranean. Migration then occurred along the coasts, particularly the northern coast, of the Mediterranean as far as the temperature was suitable. As the glacial period drew to a close, sea temperatures warmed up again and the cool water

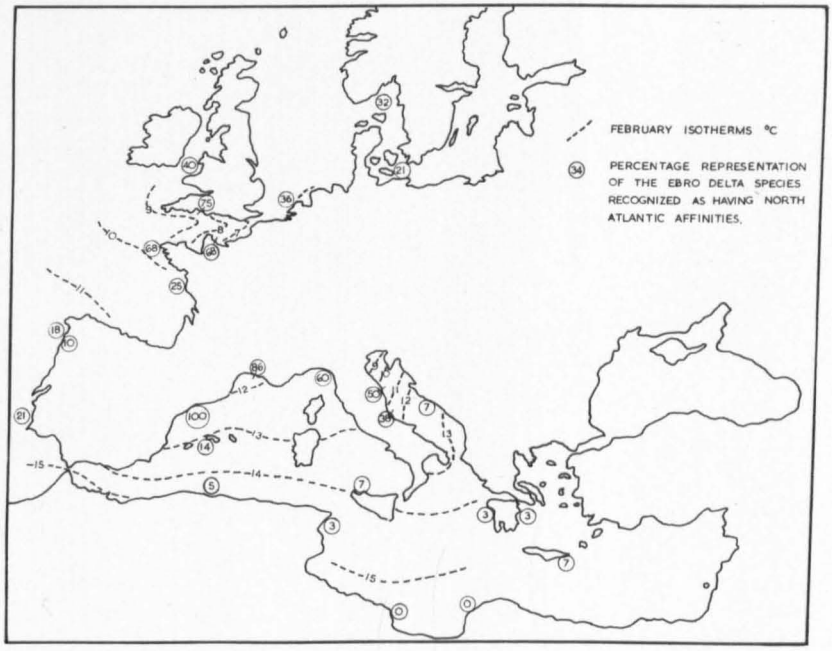


Fig. 100. Distribution of the North Atlantic element in the Ebro delta fauna. (Derived from published works and ES samples).

species gradually withdrew. However, they were unable to move southwards because the temperatures were warming from the south, and so could only withdraw to the north. As temperatures became even warmer during the interglacials they migrated to the northernmost corners of the Mediterranean and may finally have been wiped out if the temperatures became too high. Meanwhile, outside the Mediterranean, the cool water species had retreated to their original position around the British Isles. The present situation appears to represent the remains of a cool water fauna 'trapped' in the northernmost corners of the Mediterranean, the northwestern Mediterranean and the northern Adriatic, whilst outside the Mediterranean the same species have withdrawn farther north once more. It is considered that the Ebro fauna contains a 'relict' North Atlantic fauna. Figure 100 also shows the winter isotherms for the Mediterranean and North Atlantic, and it can be seen that the northernmost corners of the Mediterranean which have similar relict cool water species are also the coldest parts of the sea with winter temperatures very close to those of the English Channel. This would account for the survival of the cool water species in these areas.

The final substage of the Würm glacial period lasted from approximately 25,000 - 18,000 years B.P., and this was probably the last time that cool water species were widespread in the Mediterranean. Since then they have become progressively restricted in their distribution. Erikkson (1961) says that the final Würm substage was followed by gradual warming with a marked climatic amelioration around 11,000 years ago.

It should be emphasised that migration of foraminiferids in response to temperature changes applies particularly to shallow water species; it is not known whether deeper water species are similarly affected. Deeper waters are less susceptible to temperature

variations and deeper faunas may not have altered as did littoral faunas. Blanc (1969) stressed that under warm conditions deeper water species would migrate even deeper to seek the cooler temperatures at greater depths, and he quotes the example of Hyalinea balthica, a well known cold water species, which lives in the Mediterranean at present in the 'lower circa - littoral' zone where temperatures are constantly around 10 - 12°C. During a colder period the deeper species may migrate into shallower water.

Planktonic foraminiferids are also very useful climatic indicators and several authors (e.g. Todd, 1958) have examined them in cores from various parts of the Mediterranean. Alternations of cool water and warm water faunas have been correlated with the different Pleistocene glacial periods. Although present sea temperatures are suitable for a relatively warm water planktonic fauna, the planktonic species in the Ebro delta dead populations, and elsewhere, are predominantly cool water forms. This again may represent a 'relict' fauna; cold water planktonic species probably entered the Mediterranean during the last glacial period and may have persisted since then.

Smaller scale fluctuations in temperature are probably continuing all the time and will be reflected by small changes in foraminiferal populations. It was suggested in section d) of chapter 8 that one reason why a dead population differs from the living population at the same locality is because there may have been a recent faunal change. The previous fauna is represented in the dead population as well as the present one. Ebro delta dead populations have notably higher proportions of miliolids and Eggerella scabra than the living populations and Murray (1965a) observed that dead populations off Plymouth in the English Channel had similar high abundance of E. scabra plus species of Quinqueloculina and Cibicides lobatulus. The latter

is also found in the Ebro delta fauna, in the dead population only, although never in great abundance. Haake (1967) also noted that E. scabra is most abundant in the dead populations in an area of the Baltic Sea that he studied. Both E. scabra and C. lobatulus are recognized as cool water species and it is possible that a recent warming of the sea may have caused them to decrease in relative abundance in living faunas. Southward (1963) discussed recent chemical and biological changes in the English Channel and concluded that the best explanation for the change of fauna there in recent years is a rise in temperature. He adds (1967) that a general climatic amelioration took place from about 1900 to 1950, but in the 1960's there has been a reversal of trend with more northern species appearing. He observed a two year phase - lag between changes of sea temperature and corresponding fluctuations in barnacle populations along the south coast of England.

In conclusion it can be said that the fauna off the Ebro delta has a mixed origin. Many of the foraminiferal species present have probably evolved in the Mediterranean while others may have migrated across the Atlantic from the American Continent. However, the dominant element in the fauna is a North Atlantic one and cooling of the sea during Pleistocene glacials allowed these species to migrate down the coasts of Europe and into the Mediterranean. Following Peres (1967), (see table 11), the extra - Mediterranean distribution of the species present around the Ebro delta can be summarized as follows:

North Atlantic	33.4 %	approx.
'Central Atlantic'	15.7 %	"
Cosmopolitan	7.4 %	"
Indo - Pacific	.9 %	"
Endemic	28.7 %	"

CHAPTER 11

PALAEOECOLOGICAL IMPLICATIONS

It is proposed in this chapter to attempt to draw conclusions from the foraminiferal work that, in association with the sedimentological conclusions of chapter 6, will be of use in identifying deltaic deposits in the geological column. It is necessary firstly to distinguish deltaic deposits from non - deltaic deposits and secondly to distinguish different environments within the deltaic deposits. Care has to be taken with application of ecological conclusions from the work on living foraminiferids; fossil assemblages are usually thanatocoenoses and therefore information concerning the dead population is more appropriate from a palaeoecological point of view. However, living assemblages do provide some general information and it is vital to study them to obtain valid ecological data about different species and to ascertain whether the dead populations are locally derived, modern ones. Murray (1965a) points out that the dead population in parts of the English Channel off Plymouth is considerably different from the living one, probably containing many derived and pre - Recent specimens. Application of such dead population results could prove very misleading. In the case of the Ebro delta, the dead population is a good reflection of the living one and information derived from it can safely used for palaeoecological application.

Only rarely do biocoenoses (living assemblages) become preserved.

Myers (1942) noted that wind - induced turbulence during storms greatly disturbed bottom sediments so that at least 80 % of benthic foraminiferids were buried to depths from which they could not escape. Cytological evidence showed that the individuals died after several weeks and the protoplasm was decayed by bacteria. Murray (1961) questioned Myers' results since he partly based his percentage value on the amount of pyrite in the tests; Murray claims that this can form syngenetically. Nevertheless, it does seem possible that heavy sedimentation can inter biocoenoses and more rapid than usual sedimentation off a river mouth may frequently 'preserve' living populations.

Distinguishing different environments within a deltaic complex should be possible on the basis of foraminiferids. The ratio of the three suborders, Miliolina / Textulariina / Rotaliina, drawn up on a triangular plot may provide some information. Figure 95 in the section on the dead population in chapter 8 illustrates that there is a marked distinction between inshore and offshore assemblage fields. As these two assemblages correspond to delta - front platform and pro delta slope environments respectively, it is therefore possible to distinguish the latter on the basis of their foraminiferal faunas. In addition, pro delta deposits will contain planktonic species, the relative abundance of which increases away from shore. The deltaic marine assemblage does not plot in a distinct field but within a deltaic unit sediments deposited directly off a river channel may be recognized by the following characteristics:

1. A relatively thick mass of evenly deposited silts and clays with a relatively high organic content.
2. Relatively low numbers of foraminiferids per unit volume of sediment.
3. The relatively small size of individuals of foraminiferid species compared with individuals of the same species in other environments.

The subaerial environments tend to be much more variable in their proportions of the three suborders and are not easy to separate on the triangular plot. However, other non - specific faunal characteristics will assist in identifying them. They all have very low diversity and one species usually makes up the bulk of the fauna. Figure 101 shows that in the Ebro delta dead populations, like the living populations, the percentage of the dominant species increases as depth decreases, or as Walton (1964) states, "The percentage occurrence of the most common species in a population is directly proportional to the variability of the environment".

Off the Ebro delta diversity increases away from shore and levels out at about 30 - 40 m. depth; greatest diversity occurs on the proximal pro delta slope. On the basis of diversity it is possible to list the environments in descending order:

Pro delta slope
Deltaic marine
Delta front platform / lagoon
Lacustrine
Marsh

Delta front platform deposits can be distinguished from lagoonal deposits on their sedimentary character; the former are invariably more sandy. In addition, lagoons, because of their relatively slow rate of sedimentation, may stand out with relatively high numbers of foraminiferids per unit volume of sediment. Marsh deposits are also unmistakable in their sedimentary character, being largely organic in composition.

Distinguishing deltaic deposits from non - deltaic deposits may not always be easy but the following features should be borne in mind. Within a deltaic unit there will probably be a number

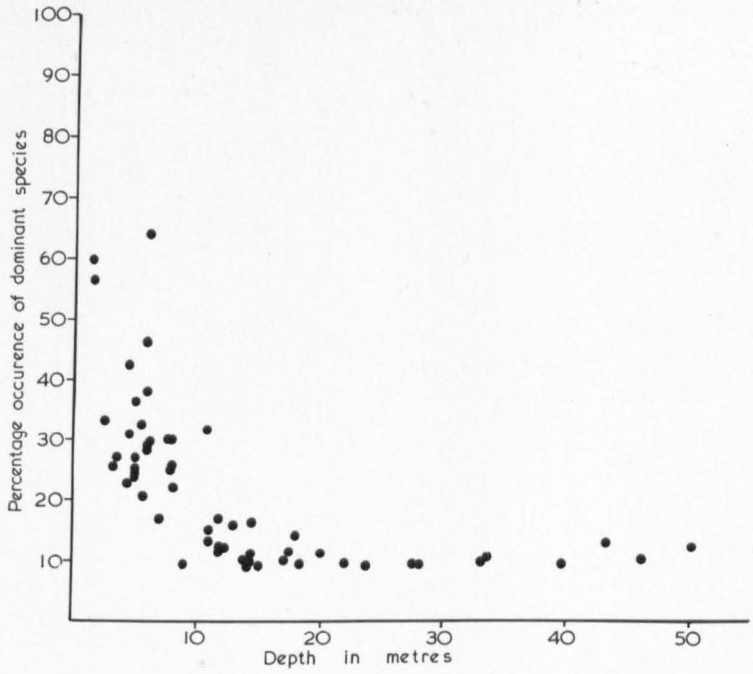


Fig. 101. Plot of percentage of dominant species in dead populations against depth.

of complexly interdigitating faunal and sedimentary groups, varying both laterally and horizontally. The subaerial environments alternate frequently on a relatively small scale and they may be occasionally interdigitated with transgressive marine deposits, perhaps representing a destructive phase in the delta's history. Generally the offshore deposits will form the greatest thicknesses of sediments, particularly pro delta silts and clays. The faunas of the offshore deltaic deposits may not be easily distinguishable from those of non - deltaic areas of shelf sediments but it may be possible to detect deltaic marine assemblages by the features described earlier. In addition, modern deltaic sediments have a relatively high content of organic detritus. Among Shepard's (1960) criteria for recognizing ancient deltas is a general scarcity of invertebrates on the subaerial parts which, if found, show little diversity of species. He also noted also noted that dominance of ostracodes over foraminiferids and a scarcity of echinoderms is indicative of a freshwater marsh.

It was tentatively suggested in chapter 8 that some species such as Nonionella opima and Epistominella vitrea are typical deltaic forms, or at least reach maximum abundance under deltaic conditions. The presence of such species may identify deltaic deposits although a good deal more work needs to be done to confirm their affinities. However, most modern species do not extend beyond the Miocene and interpretation of pre - Miocene assemblages at species level may not be possible. Walton (1964) considered that the most useful foraminiferal criteria for extrapolating modern environments into the geologic past were on a generic level but the author cannot wholly support this.

Because of complications introduced by relative rates of sedimentation, interpretation of fossil assemblages is best limited to qualitative rather than quantitative criteria. A number of difficulties may arise in interpretation, especially whether a particular assemblage,

or thanatocoenose, represents the environment in which it was discovered. Local horizontal or vertical mixing may be brought about by the activities of mud - burrowing or mud - eating animals. Storm induced turbulence and currents may redistribute tests or introduce exotic forms from other environments. There is also the possibility of bulk displacement of sediments such as was described in chapter 9, or diagenetic changes during the compaction and subsequent history of the rocks.

However, these difficulties will only confuse deltaic features on a small scale. The general characteristics outlined above should give a clear indication of deltaic deposits and a good sample coverage will yield sufficient information to distinguish deltaic environments on their sedimentary characters and foraminiferal faunas.

CHAPTER 12

SYSTEMATIC DESCRIPTIONS

Introduction

The system of classification adopted in this thesis follows that of Loeblich and Tappan (1964). Species have been identified by means of the Catalogue of Foraminifera, microfilm edition, (Ellis and Messina, 1948 et. seq.), and by reference to original publications where possible. In addition, the greater part of the Recent Foraminifera collection in the Protozoa section of the British Museum of Natural History was examined, particularly the type specimens deposited there. A number of topotypes were also studied and in all cases reference is made in the text to any holotype, topotype or hypotype specimens that have been examined for comparison with Ebro delta specimens.

In all, 126 species are listed, 115 of which were discovered living in the various environments. The remaining 11 species were found only in the dead population or in core samples and are designated by a double asterisk. Only the 57 most common species are described in detail although no attempt has been made to list the full synonomy; only the main taxonomic changes are included. The remaining species are simply listed with their type references. All species have been photographed by means of a scanning electron microscope and reference is made in the text to plate and figure numbers of each. Type slides containing the Ebro delta hypotype specimens have been presented to the British Museum, Protozoa section, for inclusion in the Recent Foraminifera collection.

Phylum P R O T O Z O A Goldfuss 1817

Order FORAMINIFERIDA Eichwald 1830

Suborder TEXTULARIINA Delage & Herouard 1896

Superfamily AMMODISCACEA Reuss 1862

Family Saccamminidae Brady 1884

Psammosphaera bowmani HERON - ALLEN & EARLAND

Plate 1, figure 1.
B.M. no. 1969:4:30:1

Heron - Allen and Earland 1912: On some Foraminifera from the North Sea dredged by the Fisheries cruiser 'Goldseeker'. Pt. 1. On some new Astrorhizidae and their shell structure. Roy. Micr. Soc. Jour. p. 385, pl. 5, figs. 5-6.

Saccammina atlantica (CUSHMAN)

Plate 1, figures 2a, 2b
B.M. no. 1969:4:30:2

Proteonina atlantica Cushman 1944: Foraminifera from the shallow water off the New England coast. Contr. Cushman Lab. Foram. Res. Spec. Publ. no. 12, p. 5, pl.1, fig. 4.

Reophax atlantica various authors

Description: Test free, pyriform, a single chamber tapering gradually to the apertural end; aperture terminal, rounded: wall very coarsely arenaceous; dimensions of hypotype: length 0.52 mm., max. diameter 0.32 mm.

Remarks: Although the outline is often similar, this species is easily distinguished from S. difflugiformis by its larger size and more coarsely arenaceous test.

Saccammina comprima (PHLEGER & PARKER)

Plate 1, figure 3
B.M. no. 1969:4:30:3

Proteonina comprima Phleger and Parker: Ecology of Foraminifera, Northwest Gulf of Mexico. Part II, Foraminifera species.
Geol. Soc. America Mem. no. 46, 1951, pt. 2, pl. 1, figs. 1 - 3.

Reophax comprima various authors

Description: Test free, compressed, a single chamber, ovate in outline but tapering towards the apertural end: aperture terminal, ovate, without a distinct neck: wall agglutinated with a rough surface of sand grains of various sizes, weakly cemented: size of hypotype: length 0.46 mm., width 0.24 mm., thickness 0.20 mm.

Saccammina difflugiformis (BRADY)

Plate 1, figure 4
B.M. no. 1969:4:30:4

Reophax difflugiformis Brady 1879: Some notes on some of the reticularian Rhizopoda of the Challenger

expedition.
Quart. Jour. Micr. Soc. n.s. vol. 19, p. 51, pl. 4, figs. 3a - b.

Proteonina difflugiformis various authors

Description: Test free, pyriform, with a single chamber; aperture terminal, rounded, at end of a slight neck: wall agglutinated; surface texture fairly smooth; dimensions of hypotype: length 0.55 mm., max. diameter 0.29 mm.

Remarks: Brady's syntypes were examined at the British Museum (slide no. 85:10:3:28); some have a very pronounced flask shape, but there are many specimens that are identical to the Ebro delta specimens.

Saccammina laguncula (RHUMBLER)

Plate 1, figure 5
B.M. no. 1969:4:30:5

Lagenammina laguncula Rhumbler 1911: Plankton - Exped. Humboldt Stiftung, Ergeb., Kiel u. Leipzig.
Bd. 3, L.c., pp. 92 - 111, pl. 1, fig. 4.

Superfamily LITUOLACEA de Blainville 1825

Family Hormosinidae Haeckel 1894

Reophax cylindrica BRADY

Plate 1, figure 6.
B.M. no. 1969:4:30:6

H.B. Brady 1884: Report on the Foraminifera

dredged by H.M.S. Challenger during the years 1873 - 1876.
Repts. Challenger Exped. Zool. Pt. 22, vol. 9, p. 299, pl. 32, figs. 7 - 9.

Reophax dentaliniformis (BRADY)

Plate 2, figure 1
B.M. no. 1969:4:30:7

Lituola dentaliniformis Brady 1881: Notes on some of the reticularian Rhizopoda of the Challenger expedition.
Quart. Jour. Micr. Soc. n.s. vol. 21, p. 49, (Type figure: Brady 1884: Challenger Repts. Zool. vol. 9, pl. 30, figs. 21 - 22).

Reophax c.f. R. fusiformis (WILLIAMSON)

Plate 2, figure 2
B.M. no. 1969:4:30:8

Proteonina fusiformis Williamson 1858: On the Recent Foraminifera of Great Britain.
Ray Soc. p.1, pl. 1, fig. 1.

Reophax moniliforme SIDDALL

Plate 2, figure 3
B.M. no. 1969:4:30:9

Siddall J.D. 1886: Report on the Foraminifera of the L.M.B.C. District, In: Liverpool

Marine Biological Committee Repts. no. 1. The first report upon the fauna of Liverpool Bay and the neighbouring seas.
Lit. Phil. Soc. Liverpool Proc. vol. 40, p.54.

Reophax nana RHUMBLER

Plate 2, figure 4
B.M. no. 1969:4:30:10

Rhumbler L. 1911: Plankton - Exped. Humboldt Stiftung, Ergerb. Kiel u. Leipzig.
Bd. 3, L.c., p. 182, pl. 8, figs. 6 - 12.

Reophax scorpiurus DE MONTFORT

Plate 2, figure 5
B.M. no. 1969:4:30:11

Denys de Montfort 1808: Conchyliologie systematique et classification méthodique des coquilles.
F. Schoell, Paris, tome 1, p. 331, type figure p. 330.

Description: Test free, elongate, uniserial rectilinear: chambers about 6 in the adult specimen, increasing considerably in size as added, final chamber considerably larger and more inflated than the rest; sutures horizontal, depressed, not always distinct in the earlier part of the test; aperture terminal, rounded, at end of tubular neck; wall agglutinated, surface rough; dimensions of hypotype: length 0.94 mm., max. diameter 0.24 mm.

Reophax scottii CHASTER

Plate 2, figures 6a - b
B.M. no. 1969:4:30:12

Reophax nodulosa (?) Scott 1860: 8th Ann. Rept. Fishery Board of Scotland, Pt. III, p. 314.

Reophax scottii Chaster 1892: Report on the Foraminifera of the Southport Society of Natural Science District.
Southport Soc. Nat. Sci. Rept. 1st Rept. (1890 - 1891) Append. p. 57, pl. 1, fig. 1.

Description: Test free, elongate, straight or slightly arcuate, uniserial, compressed; chambers numerous, usually 12 or more in the adult specimen, ovate to subtriangular in outline with a subacute periphery, lower margin of each chamber horizontal, tapering to apertural end, each chamber slightly overlapping the previous one; aperture terminal on final chamber, a small narrow slit; wall finely arenaceous, composed of plate - like particles slightly overlapping each other; test translucent, flexible when wet; dimensions of hypotype: length 0.51 mm., max. width 0.08 mm.

Remarks: Chaster's syntypes in the British Museum (slide 1955:10:25:490 - 496) generally have more globular, less compressed chambers and a slightly coarser arenaceous texture, but two of the specimens are identical with the Ebro delta hypotype. The latter are also identical with specimens collected off Millport in the Heron - Allen collection in the British Museum (slide 1955:10:20:167 - 177).

Reophax subfusiformis EARLAND

Plate 2, figure 7
B.M. no. 1969:4:30:13

Earland A. 1933: Foraminifera Pt. II: South Georgia.
Discovery Repts. vol. 7, p. 74, pl. 2, figs. 16-19.

Family Nouriidae Chapman and Parr 1936

Nouria polymorphides HERON - ALLEN & EARLAND

Plate 2, figure 8
B.M. no. 1969:4:30:14

Heron - Allen and Earland 1914: Foraminifera of the Kerimba Archipelago.
Trans. Zool. Soc. London vol. 20, pt. 12, p. 376, pl. 37, figs. 1 - 15.

Family Rzehakinidae Cushman 1933

Miliammina fusca BRADY

Plate 2, figure 9
B.M. no. 1969:4:30:15

Brady 1870: Ann. Mag. Nat. Hist. London ser. 4, vol. 6, p. 286, pl. 11, figs. 2 - 3.

Family Lituolidae de Blainville 1825

Haplophragmoides canariensis (D'ORBIGNY)

Plate 2, figure 10
B.M. no. 1969:4:30:16

Nonionina canariensis A. d'Orbigny 1839: Foraminifères des Iles Canaries.
Hist. Nat. des Iles Canaries, P. Barker - Webb & Sabin Berthelot, Bethune, Paris, tome 2, pt. 2, Zool., p. 128, pl. 2, figs. 33 - 34.

Description: Test free, planispiral, involute, biumbonate, slightly compressed, periphery rounded; chambers inflated, usually 6 in the final whorl, increasing rapidly in size as added; sutures distinct, radial and depressed; umbilici fairly small and depressed; aperture a narrow interiomarginal, equatorial slit; wall agglutinated, of fine sand grains giving a smooth surface; dimensions of hypotype: Max. diameter 0.39 mm., min. diameter 0.31 mm., thickness 0.17 mm.
Remarks: Specimens from the Ebro delta agree well with specimens from various parts of the Atlantic region in the Brady and Heron - Allen collections in the British Museum.

Ammobaculites c.f. A. arenaria NATLAND

Plate 3, figure 1
B.M. no. 1969:4:30:17

M.L. Natland 1938: New species of Foraminifera off the west coast of North America and from the later Tertiary of the Los Angeles basin. Bull. Scripps Inst. Oceanogr. Tech. Ser. vol. 4, pt. 5, p. 139, pl. 3, figs. 1 - 2.

Ammotium c.f. A. salsum (CUSHMAN & BRÖNNIMAN)

Plate 3, figure 3
B.M. no. 1969:4:30:18

Ammobaculites salsus Cushman & Brönniman 1948: Contr. Cushman

Lab. Foram. Res. vol. 24, pt. 1, p. 16, pl. 3, figs. 7 - 9.

Family Textulariidae Ehrenberg 1838

Textularia calva LALICKER

Plate 3, figure 3
B.M. no. 1969:4:30:19

C.G. Lalicker 1935: Two new Foraminifera of the genus Textularia.
Smithsonian Inst. Misc. Coll. Washington, vol. 91, pt. 22, p. 1, pl. 1, figs. 1 - 2.

Description: Test free, biserial, subtriangular in outline from the side and subcircular in end view; chambers numerous, broad, increasing in size as added, early chambers slightly compressed; sutures generally indistinct except in the later part of the test where they become a little depressed; aperture a low broad slit along the inner edge of the last formed chamber; wall agglutinated with a fairly rough texture apart from a smooth apertural face; dimensions of hypotype: length 0.78 mm., max. width 0.45 mm., max. thickness 0.36 mm.

Remarks: The type locality for this species is near Puerto Rico, but it has commonly been described from the Mediterranean. Parker (1958) recorded it from cores from the eastern Mediterranean and she notes that Lalicker positively identified some of her specimens from off the Island of Delos.

Textularia tenuissima EARLAND

Plate 3, figure 4
B.M. no. 1969:4:30:20

Earland E. 1933: Discovery Repts. vol. 7, p. 95, pl. 3, figs. 21 - 40.

Textularia sp. **

Plate 3, figure 5
B.M. no. 1969:4:30:21

Family Trochamminidae Schwager 1877

Trochammina c.f. T. advena CUSHMAN

Plate 3, figures 6a - b
B.M. no. 1969:4:30:22

Cushman 1922: Shallow water Foraminifera of the Tortugas region.
Carnegie Inst. Washington Publ. no. 311, p. 20, pl. 1, figs. 2 - 4.

Description: Test free, trochospiral, outline lobulate, periphery rounded; chambers inflated, ovate, increasing in size as added, four in final whorl, 2 - 2½ whorls in the adult specimen, all chambers visible from the spiral dorsal side, only those of last whorl visible ventrally; ventral umbilicus slightly depressed; aperture a low extra - umbilical - umbilical arch: wall agglutinated, composed of small sand grains giving a smooth surface texture; dimensions of hypotype: max. diameter 0.40 mm., min. diameter 0.36 mm., max. thickness 0.24 mm.

Trochammina inflata (MONTAGU)

Plate 3, figure 7a - b
B.M. no. 1969:4:30:23

Nautilus inflatus Montagu 1808: Testacea Britannica, Supplement. Exeter, p. 81, pl. 18, fig. 3.

Trochammina lobata CUSHMAN

Plate 4, figures 1a - b
B.M. no. 1969:4:30:24

J.A.Cushman 1944: Foraminifera of the New England coast.
Contr. Cushman Lab. Foram. Res. Spec. Publ. no. 12, p. 18, pl. 2, fig. 10.

Description: Test free, biconvex, periphery subacute, trochoid, two whorls in the adult specimen; chambers distinct, the last formed parts may be slightly inflated near the sutures, 6 - 8 in final whorl, increasing gradually in size as added; all chambers visible from the dorsal side, only those of final whorl visible ventrally; last formed chamber has a large lobe extending to cover the ventral umbilicus: sutures distinct, slightly depressed, more curved dorsally than ventrally; aperture ventral beneath umbilical lobe of final chamber; wall agglutinated, of fine sand grains giving a smooth surface texture; dimensions of hypotype: max. diameter 0.35 mm., min. diameter 0.25 mm., thickness 0.12 mm.

Remarks: Ebro delta specimens have a more acute periphery than the type figures of Cushman's holotype, and the inflation of the leading edges of the chambers often gives a more lobulate outline. However, the features of this species are distinct enough for

them to be placed without much doubt alongside Cushman's specimen.

Trochammina sp.

Plate 4, figures 2a - b
B.M. no. 1969:4:30:25

Ammosphaeroidina sphaeroidiniformis (BRADY)

Plate 4, figure 3
B.M. no. 1969:4:30:26

Haplophragmium sphaeroidiniforme H.B. Brady 1884: Repts. Challenger Exped. Zool. pt. 22, vol. 9, p. 313.

Description: Test free, subspherical, streptospiral; chambers few, only the three of the final whorl visible, globular: sutures distinct, depressed; aperture a narrow interiomarginal arch; wall agglutinated, usually with a fairly smooth surface; dimensions of hypotype: max. diameter 0.28 mm., min. diameter 0.18 mm.
Remarks: Brady's type locality for this species is in the Mediterranean, and it has also been recorded from the Atlantic and the Pacific.

Jadammina macrescens (BRADY)

Plate 4, figure 4
B.M. no 1969:4:30:27

Trochammina inflata Montagu var. macrescens H.B. Brady 1874: An analysis and description of the Foramifera. In Brady G.S. and Robertson D. The Ostracoda and Foraminifera of tidal rivers. Ann. Mag. Nat. Hist. ser. 4, vol. 6, p. 290, pl. 11, figs. 5a - c.

Family Ataxophragmiidae Schwager 1877

Eggerella scabra (WILLIAMSON)

Plate 4, figure 5
B.M. no. 1969:4:30:28

Bulimina scabra Williamson 1858: On the Recent Foraminifera of Great Britain.
Ray Soc. p. 65, pl. 5, figs. 136, 137.

Verneulina polystropha (Reuss) Heron - Allen and Earland, Parker and Jones, Brady, Wright etc.

Verneuilina scabra (Williamson) Cushman 1922: U.S. Nat. Mus. Bull. vol. 104, pt. 3, p. 55.

Eggerella scabra (Williamson) Cushman 1937: Spec. Publ. Cushman Lab. no. 8, p. 50 - 51, pl. 5, figs. 10, 11.

Description: Test free, elongate, triserial, increasing in width towards aperture: chambers inflated, especially the later ones; sutures more distinct in later portion of test, gently curved, slightly depressed; aperture a small ovate opening at base of terminal chamber lying in the sutural depression between the last two chambers; wall agglutinated, composed of fairly fine sand grains, and having a moderately rough surface texture; dimensions of hypotype: length 0.49 mm., max. diameter 0.30 mm.

Remarks: Apart from having slightly more distinct chambers, Ebro delta specimens are identical with Williamson's syntypes deposited in the British Museum (slide 96:8:13:30). Other collections in the British Museum, such as the Brady and Heron - Allen and Earland collections, also contain identical specimens, but usually wrongly referred to Verneuilina polystropha (Reuss).

Eggerella advena (CUSHMAN)

Plate 4, figure 6
B.M. no. 1969:4:30:29

Verneuilina advena J.A. Cushman 1922: Contr. Canadian Biol. 1921, no. 9, p. 141.

Clavulina obscura CHASTER

Plate 4, figure 7
B.M. no. 1969:4:30:30

Description: Test free, elongate, straight, circular in section; chambers not very distinct, and so arrangement in earlier part of test is obscure, later chambers uniserial, subcylindrical, slightly inflated, increasing in size as added, final chamber largest and tapers slightly towards the aperture; sutures indistinct except in later part of test where they are horizontal and slightly depressed; aperture terminal, ovate; wall agglutinated, of small, angular sand grains giving a rough surface texture; dimensions of hypotype: length 0.26 mm., max. diameter 0.08 mm.

Remarks: Ebro delta specimens are identical with Chaster's syntypes deposited in the British Museum (slide 1955:10:25:428 - 434).

Suborder MILIOLINA Delage & Herouard

Superfamily MILIOLACEA Ehrenberg 1839

Family Fischerinidae Millet 1898

Cyclogyra incerta (D'ORBIGNY)

Plate 5, figure 1
B.M. no. 1969:4:30:31

Operculina incerta A. d'Orbigny 1839: In - Ramon de la Sagra, Histoire physique et naturelle de l'Ile de Cuba.
A. Bertrand, Paris, p. 49, vol. 8, pl. 6, figs. 16 - 17.

Cornuspira incerta various authors

Description: Test free, discoidal, planispiral, evolute; small globular proloculus, long undivided planispirally coiled second chamber which increases gradually in width towards the outer coils, $4\frac{1}{2}$ - 5 coils in the adult specimen; aperture rounded, at open end of second chamber; wall calcareous, porcellanous, translucent; dimensions of hypotype: diameter 0.28 mm., thickness 0.08 mm.

Family Nubeculariidae Jones 1875

Vertebralina striata D'ORBIGNY

Plate 5, figures 2a - b
B.M. no. 1969:4:30:32

A. d'Orbigny 1826: Tableau méthodique de la classe des Cephalopodes.
Ann. Sci. Nat. Paris ser. 1, tome 7, p. 283.

Family Miliolidae Ehrenberg 1839

Quinqueloculina depressa D'ORBIGNY

Plate 5, figure 3
B.M. no. 1969:4:30:33

A. d'Orbigny 1852: Prodrome de Paleontologie stratigraphique universelle des animaux molluscs et rayonnes.
V. Masson, Paris, vol. 3, p. 196.

Quinqueloculina laevigata (D'ORBIGNY)

Plate 5, figure 4
B.M. no. 1969:4:30:34

Triloculina laevigata A. d'Orbigny 1826: Tableau méthodique de la classe des cephalopodes.
Ann. Sci. Nat. Paris ser. 1, tome 7, p. 134.

Triloculina oblonga (Montagu) Cushman 1931: Foraminifera of the Atlantic Ocean.
U.S. Nat. Mus. Bull. 104, pt. 6, p. 57, pl. 13, fig. 4.

Miliolina laevigata (d'Orbigny) Heron-Allen and Earland 1922: Soc. Sci. Hist. Nat. Corse Bull. p. 118, pl. 1, figs. 11 - 14.

Description: Test free, elongate, subrectangular, quinqueloculine; chambers distinct, arcuate, inflated, with a rounded periphery, 3 visible on one side, 4 visible on opposite side: sutures distinct, depressed; aperture terminal on the final chamber, with a small bifid tooth that slightly projects beyond the aperture: wall calcareous, porcellanous, thin, translucent, surface bumpy; dimensions of hypotype: length 0.37 mm., width 0.22 mm., thickness 0.14 mm.

Remarks: A few specimens have a triloculine arrangement of chambers.

Quinqueloculina longirostra D'ORBIGNY

Plate 5, figures 5a - b
B.M. no. 1969:4:30:35

Frumentaria seminulum Soldanii 1795: Testaceographiae etc. vol. 3, p. 295, tab. 152, figs. F, H.

Quinqueloculina longirostra A. d'Orbigny 1826: Tableau méthodique de la classe des cephalopodes. Ann. Sci. Nat. Paris ser. 1, tome 7, p. 303.

Description: Test free, elongate, quinqueloculine, periphery acute with a narrow keel; chambers arcuate, 3 visible from one side, 4 visible from the opposite side; sutures distinct, depressed; aperture terminal, rounded, at the end of a distinct neck on final chamber; neck may have longititudinal striations and aperture has a small bifid tooth; wall calcareous, porcellanous; dimensions of hypotype: length 0.93 mm., width 0.44 mm., thickness 0.27 mm.

Remarks: This species has a long and confusing history. Soldanii was the first to record it in 1795, but d'Orbigny renamed it when he discovered it in the Pliocene of Italy. However, he did not figure the species until 1846 when he described larger forms from the Miocene of the Vienna Basin. Earlier this century, Cushman revisited the type localities in Italy and figures topotypes,

(Cushman 1945). He also recognized that Adelosina laevigata d'Orbigny was the juvenile stage of Q. longirostra and that d'Orbigny gave all the young megalospheric forms of Quinqueloculina the name 'Adelosina'. Loeblich and Tappan (1964) designated a lectotype from the original types of A. laevigata deposited in the Musée National d'Histoire Naturelle, Paris. They note that the original figures show a distinct apertural tooth but that this was apparently broken away in the lectotype. Juvenile specimens of Q. longirostra from the Ebro delta agree well with the figures of the two - chambered lectotype.

There is a great deal of morphological variation within this species and many authors have undoubtedly assigned some of the variants to other species. Weisner (1923) described several species and varieties from the Adriatic and Silvestri (1899) has noted some Adelosinas from the Pliocene of Italy (e.g. A. procera and A. zangheri) which are very similar to varieties of Q. longirostra. Kruit (1955) recognized three varieties of Triloculina longirostra from the Rhône delta, all of which can be distinguished from the Ebro delta, although they have not been separated in foraminiferal population counts.

Quinqueloculina rugosa D'ORBIGNY

Plate 5, figure 6
B.M.no. 1969:4:30:36

A. d'Orbigny 1852: Prodrome de paleontologie stratigraphique universelle des animaux mollusces et rayonnes.
V. Masson, Paris vol. 3, p. 195.

Quinqueloculina schlumbergeri (WEISNER)

Plate 6, figure 1
B.M. no. 1969:4:30:37

Quinqueloculina stelligera Schlumberger 1893: Monographie des Miliolidées du Golfe de Marseille. Soc. Zool. France Mem. Paris vol. 6, p. 68, pl. 2, figs. 58 - 59. (Not Q. stelligera Terquem 1882).

Miliolina stelligera (Schlumberger) Sidebottom 1904: Report on the Recent Foraminifera from the coast of the Island of Delos. Mem. Manchester Lit. & Phil. Soc. p. 1, pl. 14.

Miliolina schlumbergeri Weisner 1923: Die Miliolideen der östlichen Adria. Prague, 1923, p. 49, pl. 6, fig. 73.

Description: Test free, elongate, quinqueloculine; periphery acute to subacute; chambers arcuate, triangular in section in the more acute specimens; sutures distinct, slightly depressed; aperture terminal on last formed chamber, rounded, with small bifid tooth; wall calcareous, porcellanous; size of hypotype: length 0.26 mm., width 0.14 mm., thickness 0.10 mm.

Remarks: This species was first named by Schlumberger in 1893, but he used a name already used by Terquem for an Eocene species. However, Weisner renamed it in 1923.

Quinqueloculina seminulum (LINNÉ)

Plate 6, figure 2
B.M. no. 1969:4:30:38

Serpula seminulum Linné 1758: Systema naturae Ed. 10, vol. 1, p. 786.

Miliolina seminulum (Linné) Brady 1884: Repts. Challenger Exped. Zool. vol. 9, p. 157.

Quinqueloculina seminulum (Linné) Cushman 1933: Foraminifera of the Atlantic Ocean. U.S. Nat. Mus. Bull. pt. 6, p. 24, pl. 2, figs. 1 - 2.

Description: Test free, elongate, ovate in outline, quinqueloculine; chambers arcuate with a rounded to subacute periphery, 4 chambers visible on one surface, 3 chambers visible on opposite side; sutures distinct, slightly depressed; aperture rounded to ovate, terminal on last formed chamber, with a simple tooth; wall calcareous, porcellanous; dimensions of hypotype: length 0.68 mm., width 0.48 mm., thickness 0.35 mm.

Remarks: Loeblich and Tappan (1964) state "Because of the wide variety of forms included in Q. seminulum by various authors, the inadequate original description and figures and the loss of the original type, a neotype was designated from the original type locality and is here figured". (Loeblich and Tappan 1964, p. C458). These figures agree exactly with the Ebro delta specimens. Also commonly occurring around the Ebro delta is a variety of Q.seminulum which differs from the neotype in having a more elongate outline.

Quinqueloculina sp.

Plate 6, figures 3a - b
B.M. no. 1969:4:30:39

Pyrgo inornata (D'ORBIGNY)

Plate 6, figure 4
B.M. no. 1969:4:30:40

Biloculina inornata A. d'Orbigny 1846: Foraminifères fossiles du bassin tertiare de Vienne.
Gide et Comp., Paris, p. 266, pl. 16, figs. 7 - 9

Massilina secans (D'ORBIGNY)

Plate 6, figures 5a - b
B.M. no. 1969:4:30:41

Quinqueloculina secans A. d'Orbigny 1826: Tableau méthodique de la classe des cephalopodes.
Ann. Sci. Nat. Paris ser. 1, tome 7, p. 303.

Triloculina dubia D'ORBIGNY

Plate 7, figures 1a - b
B.M. no. 1969:4:30:42

Triloculina dubia A. d'Orbigny 1826: Tableau méthodique de la classe des cephalopodes.
Ann. Sci. Nat. Paris ser. 1, tome 7, p. 303.
Type figure: Fornasini 1905: R. Accad. Sci. Inst. Bologna, Mem. Sci. Nat. ser. 6, tomo 2, p. 62.

Miliolina (Adelosina) laevigata (d'Orbigny) Heron - Allen and Earland 1922: Foraminifères des sables rouges du Golfe d'Ajaccio, Corse. p. 118, pl. 11, figs. 15 - 18.

Description: Test free, elongate, triloculine; chambers arcuate with acute periphery, on one side of the test two chambers are visible and surface is flat and smooth, on opposite side three chambers are visible; sutures distinct, slightly depressed; aperture terminal on last formed chamber, rounded, with a small rudimentary tooth; wall calcareous, porcellanous, smooth apart from occasional striations near the aperture; dimensions of hypotype: length 0.73 mm., max. width 0.38 mm, max. thickness 0.23 mm.

Triloculina marioni SCHLUMBERGER

Plate 7, figures 2a - b
B.M. no. 1969:4:30:43

C. Schlumberger 1893: Monographie des Miliolidées du Golfe de Marseille.
Soc. Zool. France Mem. tome 6, p. 62, pl. 1, figs. 38 - 41.

Triloculina rotunda D'ORBIGNY

Plate 7, figures 3a - c
B.M. no. 1969:4:30:44

A. d'Orbigny 1826: Ann. Sci. Nat. Paris, ser. 1, tome 7, p. 299, no. 4.
Type figure: C. Schlumberger 1893: Soc. Zool. France Mem. tome 6, p. 64, pl. 1, figs. 48 - 50.

Description: Test free, subspherical, triloculine, periphery broadly rounded; chambers much inflated, two visible on one side, three visible on opposite side; aperture terminal on the last formed chamber, rounded, with a distinct lip and a strong bifid tooth

projecting beyond the aperture; wall calcareous, porcellanous, commonly with transverse 'wrinkles'; dimensions of hypotype: length 0.68 mm., max. width 0.52 mm., max. thickness 0.44 mm.

Triloculina sp.

Plate 7, figures 4a - b
B.M. no. 1969:4:30:45

Description: Test free, small, elongate, triloculine, slightly compressed, roughly ovate in outline, periphery rounded; chambers elongate, slightly inflated, last formed chamber significantly larger than preceding ones and is much broader at initial end narrowing towards the aperture; sutures distinct, slightly depressed; aperture terminal on the last formed chamber, rounded; wall calcareous, porcellanous, translucent; dimensions of hypotype: length 0.32 mm., max. width 0.14 mm., max. thickness 0.10 mm.

Remarks: This species is common in several of the samples from the western Mediterranean area and also from the British Isles area but no author appears to have figured or named it as yet. It varies considerably in size (English Channel specimens are generally more than twice the size of Ebro delta forms), and quinqueloculine specimens are not uncommon. It bears a good deal of similarity to Miliolinella microstoma Warren (1957), but it does not possess the 'comma - shaped' aperture that Warren describes.

Suborder ROTALIINA Delage & Herouard 1896

Superfamily NODOSARIACEA Ehrenberg 1838

Family Nodosariidae Ehrenberg 1838

Amphicoryna scalaris (BATSCH) **

Plate 8, figure 1
B.M. no. 1969:4:30:46

Nautilus (Orthoceras) scalaris Batsch 1791: Testaceorum arenulae marinae tabulae sex....
Jena Univ. Press 1791, pp. 1 - 4.

Lagena clavata (D'ORBIGNY)

Plate 8, figure 2
B.M. no. 1969:4:30:47

Oolina clavata A. d'Orbigny 1846: Foraminifères fossiles du bassin tertiare de Vienne.
Gide et Comp. Paris, p. 24, pl. 1, figs. 2-3.

Lagena c.f. L. semistriata WILLIAMSON

Plate 8, figure 3
B.M. no. 1969:4:30:48

Lagena striata (Montagu) var. β , semistriata Williamson 1884:

On some Recent British species of the genus Lagena.
Ann. Mag. Nat. Hist. ser. 2, vol. 1, p. 14, pl. 1, figs. 9 - 10.

Lagena substriata WILLIAMSON

Plate 8, figure 4
B.M. no. 1969:4:30:49

Williamson 1848: On some Recent British species of the genus Lagena.
Ann. Mag. Nat. Hist. ser. 2, vol. 1, p. 15, pl. 2, fig. 12.

Lagena sulcata (WALKER & JACOB)

Plate 8, figure 5
B.M. no. 1969:4:30:50

Serpula sulcata Walker & Jacob 1798: in "Adam's essays on the microscope". Ed. 2, Dillon and Keating, London, p. 634.

Lagena tenuis (BÖRNEMANN)

Plate 8, figure 6
B.M. no. 1969:4:30:51

Ovulina tenuis Börnemann 1855: Die mikroskopische Fauna des Septamenthones von Hermsdorf bei Berlin. Deutsch Geol. Geo. Zeitschr. Berlin, Bd. 7, Heft. 2, p. 317, pl. 12, figs. 3a - b.

Lagena vulgaris WILLIAMSON

Plate 8, figure 7
B.M. no. 1969:4:30:52

Williamson 1858: On the Recent Foraminifera of Great Britain.
Ray Soc. p. 3, pl. 1, figs. 5, 5a.

Note: Species of Lagena originally described by Williamson have all been verified against his type specimens deposited in the British Museum.

Family Glandulinidae Reuss 1860

Fissurina lucida (WILLIAMSON)

Plate 8, figure 8
B.M. no. 1969:4:30:53

Entosolenia marginata (Montagu) var. lucida Williamson 1848:

On the Recent British species of the genus Lagena.
Ann. Mag. Nat. Hist. ser. 2, vol. 1, p. 17, pl. 2, fig. 17.

Fissurina sp.

Plate 8, figure 9
B.M. no. 1969:4:30:54

Superfamily BULIMINACEA Jones 1875

Family Turrilinidae Cushman 1927

Buliminella elegantissima (D'ORBIGNY)

Plate 8, figures 10a - b
B.M. no. 1969:4:30:55

Bulimina elegantissima A. d'Orbigny 1839: Voyage dans l'Amerique Meridionale. Foraminifères. Levrault, Strasbourg, tome 5, pt. 5, p. 61, pl. 7, figs. 13 - 14.

Buliminella elegantissima (d'Orbigny) Cushman 1911: U.S. Nat. Mus. Bull. vol. 71, p. 89.

Description: Test free, fusiform, trochospiral; chambers numerous, high and narrow, very slightly inflated; sutures distinct, slightly depressed and gently curved; aperture elongate with upper end broader, at base of apertural face of last formed chamber which extends about one third down the length of the test; wall calcareous, hyaline, finely perforate, radial in structure; dimensions of hypotype: length 0.26 mm., max. diameter 0.09 mm.

Family Bolivinitidae Cushman 1927

Bolivina pseudoplicata HERON - ALLEN & EARLAND

Plate 8, figure 11
B.M. no. 1969:4:30:56

Heron - Allen and Earland 1930: The Foraminifera

of the Plymouth District. Pt. 1.
Roy. Micr. Soc. Jour. ser. 3, vol. 50, p. 81, pl. 3, figs. 36 - 40.

Brizalina c.f. B. aenariensis COSTA

Plate 9, figure 1
B.M. no. 1969:4:30:57

O.G. Costa 1856: Paleontologia del reguo di Napoli, Parte II.
Accad. Pontaniana Napoli Atti. vol. 7, fasc. 2, p. 297, pl. 15, figs. 1a, A, B.

Brizalina pseudopunctata (HÖGLUND)

Plate 9, figure 2
B.M. no. 1969:4:30:58

Bolivina punctata (d'Orbigny) Göes 1894: K. Sv. Vet.. Akad. Handl. vol. 25, pt. 9, p. 49, pl. 9.
Bolivina pseudopunctata Höglund 1947: Foraminifera of the Gulmar Fjord and the Skagerak.
Univ. Zool. Bidrag. Uppsala Bd. 26, p. 213, pl. 24, figs. 5a - b, pl. 32, figs. 23 - 34.

Description: Test free, elongate, slightly compressed, biserial, tapering to a subacute initial end, greatest breadth of test at bast of final pair of chambers; periphery rounded; chambers numerous, slightly inflated, increasing rapidly in height but more slowly in breadth as added; sutures distinct, slightly depressed, oblique and sometimes very slightly curved; aperture narrow, elongate, extending up from base of apertural face of final chamber; wall

calcareous, hyaline, distinctly perforate, radial in structure, transparent; dimensions of hypotype: length 0.37 mm., max. width 0.12 mm., max. thickness 0.07 mm.

Remarks: There is a good deal of morphological variation within this species, particularly in the degree of inflation of the chambers but the Ebro delta hypotype is very close to Höglund's type figures. It is also identical with specimens in the author's possession from the Skagerak, one of Höglund's type areas.

Brizalina spathulata (WILLIAMSON)

Plate 9, figure 3
B.M. no. 1969:4:30:59

Textularia variabilis Williamson var. spathulata Williamson 1858: On the Recent Foraminifera of Great Britain. Ray Soc. p. 76, pl. 6, figs. 164 - 165.

Bolivina dilatata (Reuss) Brady 1887: Jour. Roy. Micr. Soc. p. 900, and other British authors.

Bolivina spathulata (Williamson) Macfadyen 1931: Geol. Surv. Egypt, pp. 57 & 148, pl. 4, figs. 20a - b.

Description: Test free, biserial, elongate, compressed, twice as long as broad, thickest along axial line, thinning towards acute periphery, widest at base of final pair of chambers, tapering again towards aperture; chambers numerous, not inflated, increasing in size as added; sutures distinct, limbate, gently curved, strongly oblique; aperture loop - shaped, extending from base of final chamber; wall calcareous, hyaline, perforate, radial in structure; dimensions of hypotype: length 0.39 mm, max. width 0.19 mm., max. thickness 0.09 mm.

Remarks: B. spathulata has frequently been recorded as B. dilatata, but Macfadyen (1932) has demonstrated that the former is quite distinct, having curved chambers and sutures. There is also a

close resemblance to B. catanensis Seguenza which is common in the late Tertiary of Italy and has also been recorded living in the Mediterranean. Apart from less distinct sutures and a slightly less acute periphery, Ebro delta specimens are identical with Williamson's syntypes of Textularia variabilis var. spathulata in the British Museum (slide 96.8.13.42).

Brizalina striatula (CUSHMAN)

Plate 9, figure 4
B.M. no. 1969:4:30:60

Bolivina striatula Cushman 1922: Shallow water Foraminifera of the Tortugas region. Carnegie Inst. Washington Publ. 311 (Dept. Marine Biol. papers vol. 17) p. 27, pl. 3, fig. 10.

Description: Test free, elongate, compressed, biserial, initial end tapered, apertural end more broadly rounded; periphery rounded; test characterized by numerous fine costae running longitudinally from the initial end up to two thirds the length of the test; chambers numerous, very slightly inflated particularly in the later part of the test; sutures distinct in later portion of test, less so in early part where the close spacing of the costae frequently obscures them, slightly depressed; aperture elongate, extending up from base of apertural face of final chamber; wall calcareous, hyaline, finely perforate, radial in structure; dimensions of hypotype: length 0.43 mm., max. width 0.12 mm., max. thickness 0.08 mm.

Family Buliminidae Jones 1875

Bulimina aculeata D'ORBIGNY

Plate 9, figure 5
B.M. no. 1969:4:30:61

Polymorphium pineiformium Soldanii 1791: Testacea vol. 1, pt. 2, p. 118, pl. 127, fig. 1, pl. 130, fig. vv.
Bulimina aculeata d'Orbigny 1826: Tableau méthodique de la classe des cephalopodes.
Ann. Sci. Nat. Paris ser. 1, tome 7, p. 269, no.7.

Description: Test free, triserial; chambers globular and inflated, increasing rapidly in size as added, maximum diameter of test at base of final whorl of three chambers, tapering sharply to initial end, early chambers have small spines projecting downwards from their initial ends; sutures distinct, depressed; aperture loop - shaped, extending away from base of apertural face of final chamber; wall calcareous, hyaline, finely perforate, radial in structure; dimensions of hypotype: length 0.25 mm., max. diameter 0.15 mm.
Remarks: Ebro delta specimens agree well with others identified as B. aculeata in several of the collections in the British Museum, including those of Brady from various localities in the Mediterranean and Nyi Nyi from the Holocene of Lancashire. They are also identical to specimens from a sample from Rimini, d'Orbigny's type locality.

Bulimina elongata D'ORBIGNY

Plate 9, figure 6
B.M. no. 1969:4:30:62

d'Orbigny 1826: Tableau méthodique de la classe des cephalopodes.
Ann. Sci. Nat. Paris ser. 1, tome 7, p. 269.

Bulimina gibba FORNASINI

Plate 9, figures 7a - b
B.M. no. 1969:4:30:63

Fornasini 1902: Contributo a la conoscenza de le Bulimine adriatiche.
R. Accad. Sci. Ist. Bologna Mem. Sci. Nat. ser. 5, tomo 9, (1901 - 1902) p. 378, pl. 0, figs. 32 - 34.

Description: Test free, elongate, triserial, initial end subacute, maximum diameter of test around base of final whorl of chambers; chambers numerous, inflated, globular, later chambers have greater height than breadth, initial chambers may have a few very small spines; sutures distinct, depressed and slightly thickened; aperture ovate, elongate, extending up from base of apertural face of final chamber, with a slight rim; wall calcareous, hyaline, finely perforate, radial in structure; dimensions of hypotype: length 0.33 mm., max. diameter 0.15 mm.

Bulimina marginata D'ORBIGNY

Plate 9, figure 8
B.M. no. 1969:4:30:64

d'Orbigny 1826: Tableau méthodique de la classe des cephalopodes.
Ann. Sci. Nat. Paris ser. 1, tome 7, p. 269, pl. 12, figs. 10 - 12.

Bulimina sp. 1

Plate 10, figure 1
B.M. no. 1969:4:30:65

Bulimina sp. 2 **

Plate 10, figure 2
B.M. no. 1969:4:30:66

Reusella aculeata CUSHMAN

Plate 10, figure 3
B.M. no. 1969:4:30:67

Verneuilina spinulosa (Reuss) Brady 1884: Challenger Repts. Zool. vol. 9, p. 384, pl. 47, figs. 2 - 3.
Reussia spinulosa (Reuss) Hada 1931: Sci. Rep. Tohoku Imp. Univ. ser. 4, Biol. vol. 6, p. 133, text. fig. 90.
Reusella aculeata Cushman 1945: The species of the subfamily Reusellinae of the foraminiferal family Buliminidae. Contr. Cushman Lab. Foram. Res. vol. 21, p. 41, pl. 7, figs. 10 - 11.

Description: Test free, triserial, triangular in outline and in transverse section; periphery acute and peripheral margins of chambers thickened giving rise to backward projecting spines; chambers numerous, distinct, not inflated, increasing in size as added; sutures distinct, slightly limbate; aperture a basal opening in last formed chamber with internal tooth plate; wall calcareous, hyaline, coarsely perforate, radial in structure; dimensions of hypotype: length 0.32 mm., max. width 0.18 mm.

Family Uvigerinidae Haeckel 1894

Uvigerina sp.

Plate 10, figure 4
B.M. no. 1969:4:30:68

Description: Test free, small, triserial, rounded in section; chambers globular, inflated, early ones indistinct, final whorl of three chambers comprise about three quarters of the length of the test, and each chamber slightly overlaps preceding ones; sutures distinct, depressed; basal half of chambers covered by longitudinal costae which are produced into short spines; aperture terminal, rounded, produced on a short neck with a thin phialine lip; wall calcareous, hyaline, radial in structure, basal part of chambers conspicuously perforate; dimensions of hypotype: length 0.19 mm., max. diameter 0.12 mm.

Hopkinsina pacifica Cushman var. atlantica CUSHMAN

Plate 10, figure 5
B.M. no. 1969:4:30:69

Cushman 1944: Foraminifera of the shallow water of the New England coast.
Cushman Lab. Foram. Res. Spec. Publ. no. 12, p. 30.

Description: Test free, small, elongate, fusiform, slightly compressed; early chambers triserially arranged, later chambers biserial, inflated and increasing in size as added; sutures distinct, depressed, oblique; aperture terminal on last formed chamber, with a short neck and thin lip; wall calcareous, hyaline, finely perforate, radial in structure; dimensions of hypotype: length 0.20 mm., max. width 0.08 mm., max. thickness 0.06 mm.

Rectuvigerina c.f. R. compressa (CUSHMAN)

Plate 10, figures 6a - b
B.M. no. 1969:4:30:70

Uvigerina compressa Cushman 1925: A new uvigerinid from the Vienna Basin.
Contr. Cushman Lab. Foram. Res. vol. 1, no. 4, p. 10.

Description: Test free, elongate, about four times as long as broad, subcylindrical, early portion triserial, becoming biserial and finally uniserial for about two thirds the length of the test; chambers numerous, distinct, slightly inflated, increasing in size as added, each slightly overlapping the preceding one; sutures distinct, depressed; surface ornament of fine, distinct costae which become produced into short spines; aperture terminal, rounded, with a short, non - perforate neck and a thin, phialine lip; wall calcareous, hyaline, perforate, radial in structure; dimensions of hypotype: length 0.41 mm., max. diameter 0.14 mm.

Trifarina angulosa (WILLIAMSON)

Plate 10, figure 7
B.M. no. 1969:4:30:71

Uvigerina angulosa Williamson 1858: On the Recent Foraminifera of Great Britain.
Ray Soc. p. 67, pl. 5, fig. 140.

Superfamily DISCORBACEA Ehrenberg 1838

Family Discorbidae Ehrenberg 1838

'Discorbis' bulbosa PARKER

Plate 11, figures 1a - b
B.M. no. 1969:4:30:72

F.L. Parker 1954: Distribution of Foraminifera in the Northeast Gulf of Mexico. Contr. Scripps Inst. Oceanogr. no. 709, p. 523, pl.8, figs. 10.- 12.

Buccella hannai (PHLEGER & PARKER)

Plate 11, figures 2a - b
B.M. no. 1969:4:30:73

Eponides hannai: Phleger & Parker 1951: Geol. Soc. America Mem. vol. 46, p. 21, pl. 10, figs. 11 - 13.

Epistominella vitrea PARKER

Plate 11, figures 3a - b
B.M. no. 1969:4:30:74

F. Parker 1953: Cushman Found. Foram. Res. Spec. Publ. no. 2, p. 9, pl. 4, figs. 34 - 36.

Description: Test free, small, trochospiral, periphery rounded to subacute; chambers numerous, 6 in final whorl, about three whorls in the adult specimen, all chambers visible from convex spiral side, only those of final whorl visible on ventral side; sutures distinct, flush and oblique on dorsal side, radial and slightly depressed on ventral side; aperture an elongate narrow opening in final chamber parallel to periphery and with a very narrow lip; wall calcareous, hyaline, finely perforate, radial in structure; dimensions of hypo-

type: max. diameter 0.13 mm., min. diameter 0.11 mm., thickness 0.06 mm.

Gavelinopsis praegeri (HERON - ALLEN & EARLAND)

Plate 11, figures 4a - b
B.M. no. 1969:4:30:75

Discorbina praegeri Heron - Allen & Earland 1913: Clare Island Survey: Part 64 - Foraminifera. Roy. Irish Acad. Proc. Dublin vol. 31, sect. 3, p. 122.

Description: Test free, trochoid, plano - convex; periphery acute and slightly thickened to form a keel; outline of test subcircular, occasionally lobulate; chambers 6 - 7 to a whorl, $2\frac{1}{2}$ whorls in the adult specimen, all chambers visible from spiral dorsal side, only those of last whorl visible ventrally, not inflated on dorsal surface but later chambers slightly inflated on ventral side; sutures distinct, on dorsal side oblique, flush and slightly curved, on ventral side slightly depressed and nearly radial; ventral umbilicus has prominent umbilical plug; aperture an interiomarginal slit near periphery on umbilical side, with slight lip; wall calcareous, hyaline, finely perforate, radial in structure; dimensions of hypotype: max. diameter 0.26 mm., min. diameter 0.22 mm., thickness 0.10 mm. Remarks: The syntypes of Discorbina praegeri in the British Museum (slide 1955:10:25:41 - 44) are poorly preserved, but apart from their smaller size they appear to be identical with Ebro delta specimens. The latter are also identical with the specimen figured by Loeblich and Tappan (1964).

Rosalina concinna (BRADY)

Plate 12, figures 1a - b
B.M. no. 1969:4:30:76

Discorbina concinna Brady 1884: Challenger Repts. Zool. pt. 22, vol. 9, p. 646, pl. 90, figs. 7 - 8.

Rosalina globularis D'ORBIGNY

Plate 12, figures 2a - b
B.M. no. 1969:4:30:77

d'Orbigny 1826: Tableau méthodique de la classe des cephalopodes.
Ann. Sci. Nat. Paris, ser. 1, tome 7, p. 271, pl. 13, figs. 1-4.

Rosalina c.f. R. mediterranensis (BRADY)

Plate 12, figures 3a - b
B.M. no. 1969:4:30:78

A. d'Orbigny 1826: Tableau méthodique de la classe des cephalopodes.
Ann. Sci. Nat. Paris ser. 1, tome 7, p. 271.

Rosalina c.f. R. valvulata D'ORBIGNY

Plate 12, figures 4a - b
B.M. no. 1969:4:30:79

A. d'Orbigny 1826: In - Ramon de la Sagra -

Histoire physique et naturelle de l'Ile de Cuba. A. Bertrand, Paris, p. 96; type figure - vol. 8, pl. 3, figures 21 - 23.

Description: Test free (possibly occasionally attached), plano - convex, subcircular in outline, periphery acute; chambers numerous, usually 5 in final whorl; all chambers visible dorsally, only those of final whorl visible ventrally, slightly inflated on spiral dorsal side; sutures distinct, curved and depressed on dorsal side; aperture a low interiomarginal arch at base of final chamber, with chamber flap beneath aperture reaching into open umbilicus, secondary sutural aperture opens on opposite side of flap and those of previous chambers also remain open; wall calcareous, hyaline, perforate, radial in structure; dimensions of hypotype: max. diameter 0.22 mm, min. diameter 0.17 mm., thickness 0.06 mm.

Valvulineria complanata (D'ORBIGNY)

Plate 13, figures 1a - b
B.M. no. 1969:4:30:80

Rosalina complanata A. d'Orbigny 1846: Foraminifères fossiles de la bassin tertiare de Vienne. Gide et Comp. Paris, p. 175, pl. 10, figs. 13 - 15.

Discorbina saulcii (d'Orbigny) Brady 1884: Challenger Repts. Zool. vol. 9, p. 653, pl. 91, fig. 6.

Discorbina bradyana Fornasini 1900: Mem. R. Accad. Sci. Ist. Bologna ser. 5, vol. 8, p. 393, text fig. 43.

Valvulineria mediterranensis (d'Orbigny) Kruit 1955: Sediments of the Rhône delta. Mouton and Co. p. 115, pl. 2, fig. 14.

Valvulineria complanata (d'Orbigny) Parker 1955: Eastern Mediterranean Foraminifera.

Repts. Swedish Deep Sea Exped. vol. 8, p. 268, pl.3, figs. 42 - 44.

Description: Test free, trochoid; periphery rounded; chambers slightly inflated, especially on the ventral surface, usually 7 in final whorl, increasing rapidly in size as added, all chambers visible from the flat, spiral dorsal side, only those of final whorl visible ventrally; sutures distinct, flush, curved and slightly oblique dorsally, less curved and more depressed ventrally; aperture interiomaginal extra - umbilical - umbilical with broad apertural flap covering the umbilicus; wall calcareous, hyaline, radial in structure, very coarsely perforate, although basal half of apertural face of final chamber non - perforate; dimensions of hypotype: max. diameter 0.35 mm., min. diameter 0.29 mm., thickness 0.20 mm.

Remarks: D'Orbigny's type comes from the Miocene of the Vienna Basin, and his type figures agree well with Ebro delta specimens apart from having a subacute periphery. A sample in the author's possession from the Miocene of the Vienna Basin (but not from d'Orbigny's type locality) has yielded specimens identical to those living around the Ebro delta. V. complanata seems to be essentially a Mediterranean species, common in the Upper Tertiary of southern Europe and living at present through much of the peripheral Mediterranean area. However, it seems to have been consistently misidentified by many authors. Both Brady and Sidebottom have referred it to Discorbina saulcii d'Orbigny (Brady's specimens from the Gulf of Scala, Nova Levant, have been examined - B.M. slide no. 1955:6:5: 849 - 876 - and they are identical with Ebro delta specimens). Parker (1958) noted the presence of V. complanata in cores from the Eastern Mediterranean and added that it has frequently been referred by many Mediterranean workers to Discorbina bradyana Fornasini, although Fornasini's original outline drawings bear little resemblance to the species.

Family Asterigerinidae d'Orbigny 1839

Asterigerinata sp.

Plate 13, figures 2a - c
B.M. no. 1969:4:30:81

Description: Test free, trochoid, plano - convex; periphery subacute and slightly lobulate; chambers numerous, 4 - 5 in final whorl, 2½ - 3 whorls in adult specimen, all chambers visible from dorsal side which is a high spiral, only those of final whorl visible on flat ventral side and these are very slightly inflated; umbilical region on ventral side occupied by 3 or 4 very small, slightly inflated secondary chamberlets; sutures distinct, oblique, slightly curved and flush on dorsal side, less oblique and a little depressed on ventral side; aperture an elliptical opening on inner side of ventral face of final chamber; wall calcareous, hyaline, distinctly perforate, radial in structure; dimensions of hypotype: diameter 0.13 mm., height 0.12 mm.

Asterigerinata mamilla (WILLIAMSON)

Plate 13, figures 3a - b
B.M. no. 1969:4:30:82

Rotalina mamilla Williamson 1858: On the Recent Foraminifera of Great Britain.
Ray Soc. p.54, pl. 4, figs. 109 - 111.
Discorbis mamilla (Williamson) Phleger et al. 1953: Repts. Swedish Deep Sea Exped. vol. 7, no. 1.

Description: Test free, trochoid, plano - convex; periphery acute, carinate and lobulate; chambers numerous, 4 - 5 in final whorl,

slightly inflated, especially on ventral side, all chambers visible from spiral dorsal side, only those of final whorl visible ventrally and these partly obscured by 3 or 4 small, compressed secondary chamberlets arranged in a rosette around a small, indistinct umbilical plug, secondary chamberlets alternate with primary ones so that they are situated in umbilical regions of primary sutures, all chambers have radial markings on the peripheral thickenings which give the appearance of a milled edge to the test; sutures distinct, on spiral side oblique and very little depressed, on ventral side nearer radial and more depressed; aperture a distinct elliptical opening on inner side of ventral face of final chamber, with a thin lip; wall calcareous, hyaline, finely perforate, radial in structure; dimensions of hypotype: max. diameter 0.30 mm., min. diameter 0.28 mm., thickness 0.17 mm.

Remarks: Ebro delta specimens agree satisfactorily with Williamson's syntypes deposited in the British Museum.

Superfamily SPIRILLINACEA Reuss 1862

Family Spirillinidae Reuss 1862

Patellina corrugata WILLIAMSON

Plate 14, figures 1a - b
B.M. no. 1969:4:30:83

Williamson 1858: On the Recent Foraminifera of Great Britain.
Ray Soc. p. 46, pl. 3, figs. 86 - 89.

Description: Test free, conical, spiral side elevated and evolute, umbilical side flat or slightly concave and involute; chambers low,

broad and crescentic, two to a whorl, all visible on conical side, divided by numerous transverse septa giving cancellated appearance to test on conical side, do not reach across umbilical portion of test; aperture a low arch under exterior margin of scroll - like median septum of final chamber at centre of test; median septa of entire test arranged above each other to form columella; wall calcareous, hyaline, monocrystalline, finely perforate; dimensions of hypotype: diameter 0.18 mm., height 0.08 mm.

Remarks: Ebro delta specimens are identical with Williamson's syntypes deposited in the British Museum.

Superfamily ROTALIACEA Ehrenberg 1839

Family Rotaliidae Ehrenberg 1839

'Rotalia' perlucida HERON-ALLEN & EARLAND

Plate 14, figures 2a - b
B.M. no. 1969:4:30:84

Heron - Allen and Earland 1913: Clare Island Survey. Foraminifera.
Proc. Roy. Irish Acad. vol. 31, pt. 64, p. 139, pl. 13, figs. 7 - 9.

Description: Test free, trochospiral, compressed; chambers slightly inflated, 6 or 7 in final whorl, all chambers visible from dorsal side, only those of final whorl visible ventrally; sutures distinct, on dorsal surface very little depressed and curved, on ventral side nearer radial and more depressed; ventral umbilicus depressed; aperture obscure but appears to be a row of pores at the base of apertural face of final chamber; wall calcareous, hyaline, distinctly perforate, radial in structure; dimensions of hypotype: max. diameter 0.33 mm., min. diameter 0.26 mm., thickness 0.12 mm.

Remarks: Unfortunately, the type specimens of this species originally kept in the British Museum have been destroyed. However, Ebro delta specimens agree fairly closely with Heron - Allen and Earland's type figures although the latter have a more lobulate outline. The authors record that there is considerable morphological variation within this species and this is characteristic of Ebro delta specimens as well.

The generic position of the species is uncertain. It is not strictly a Rotalia as originally described since there are none of the tubercles and fissures on the ventral surface characteristic of this genus. If it were not trochospirally coiled it could be placed within the genus Protelphidium. Its coiling suggests a position within the Discorbacea but it does not fit satisfactorily into any of the genera in Loeblich and Tappan's classification. It may well prove necessary to erect a new genus to accommodate this species.

Ammonia beccarii (LINNÉ)

Plate 14, figures 3a - b
B.M. no. 1969:4:30:85

'Cornu Hammonis' Plancus 1739: Conch. Min. p. 8, pl. 1, fig. 1.
'Ammonita unita' Gualtieri 1742: Testaceographia vol.1, pt. 1, p. 56, pl. 35, fig. R.
Nautilus beccarii Linné 1767: Systema Naturae Ed. 12, p. 1162.
Ammonia beccarii (Linné) Brünnich 1771: Ammonia Brünnich, M.T., Zoologiae fundamenta Praelectonibus Academias Accomodata, p. 246.
Streblus beccarii (Linné) Fischer 1819: Advers. Zool. fasc. 2 p. 75.
Rotalia (Turbinulina) beccarii (Linné) d'Orbigny 1826: Ann. Sci. Nat. Paris ser. 1, tome 7, p. 275, no.42.

Description: Test free, biconvex, trochospiral, compressed, periphery rounded; chambers numerous, 13 in final whorl, all chambers visible from from spiral dorsal surface, only those of final whorl visible ventrally; sutures distinct, on dorsal surface slightly curved and strongly limbate and inner whorls of chambers often obscured by the strongly developed sutural thickenings, on ventral surface radial with irregular granular deposits alongside, depressed and becoming very deeply excavated towards umbilicus; umbilicus deeply excavated with numerous pillars and bosses of granular material; aperture a low interiomarginal arch; wall calcareous, hyaline, radial in structure; dimensions of hypotype: max. diameter 1.21 mm., min. diameter 1.12 mm., thickness 0.56 mm.

A. beccarii (Linné) var. batavus (HOFKER)

Plate 14, figures 3c - d
B.M. no. 1969:4:30:86

Streblus batavus Hofker 1951: Siboga Exped. Monogr. Leiden no. 46, pp. 498, 500 - 502, text figures 335, 340, 341.

Distinguished by stronger convexity on ventral surface, dorsal surface often flat; chambers 7 - 9 in final whorl, moderately inflated; sutures slightly thickened and not so deeply excavated on ventral side.

A. beccarii (Linné) var. 1

Plate 15, figure 1b
B.M. No. 1969:4:30:86

Differs from typical form in its smaller size, higher trochoid spire, fewer chambers (7 - 8) which are slightly inflated to give a more lobulate outline; sutures not so thickened; umbilicus very

deeply excavated but lacks granular deposits around it.

A. beccarii (Linné) var. 2

Plate 15, figure 1c
B.M. no. 1969:4:30:86

Distinguished by its very small size, lobulate outline; 5 - 6 inflated chambers; umbilicus very little depressed, filled with granular material that extends into umbilical region of sutures.

A. beccarii (Linné) var. 3

Plate 15, figure 1a
B.M. no. 1969:4:30:86

Distinguished by its smooth, subcircular outline and distinct ventral umbilical boss; it is also relatively thin compared with other varieties.

Remarks: The early history of the taxonomy is very confused owing to inadequate type descriptions and figures. Linnaeus first named it in 1767 and referred to the earlier figures of Plancus and Gualtieri which were extremely poor. Unfortunately, it appears that the type specimen is lost, but after Nautilus beccarii was first named it was made the type species of four or five genera by various authors. Following Loeblich and Tappan (1964), Ammonia is the genus that has priority.

Ammonia beccarii exhibits five distinct varieties around the Ebro delta, each having its own environmental preferences. The cosmopolitan distribution of the species and its frequent morphological variation from area to area undoubtedly added to the confusion in its taxonomy. The typical A. beccarii is identical with specimens from a sample from Rimini, which was the type locality of Linné.

Family Elphidiidae Galloway 1933

Elphidium advenum (CUSHMAN)

Plate 15, figure 2
B.M. no. 1969:4:30:87

Polystomella subnodosa Brady (non Von Munster) 1884: Challenger Repts. Zool. vol. 9, p. 734, pl. 110, figs. 1a - b.
Polystomella advena Cushman 1922: Carnegie Inst. Washington Publ. 311, p. 56, pl. 9, figs. 11 - 12.
Elphidium advenum Cushman 1930: U.S. Nat. Mus. Bull. 104, pt. 7, p. 25, pl. 10, figs. 1 - 2.

Description: Test free, planispiral, involute, biumbonate, compressed, periphery acute with narrow keel; chambers 10 - 15 in final whorl, last few formed may be very slightly inflated; sutures distinct, gently curved and slightly depressed; short retral processes, about 10 - 12 to the adult chamber; umbilici of medium size, slightly raised, with distinct central boss of clear shell material; aperture a series of pores at base of apertural face; wall calcareous, hyaline, finely perforate, radial in structure; translucent; dimensions of hypotype: max. diameter 0.27 mm., min. diameter 0.22 mm., thickness 0.12 mm.

Elphidium crispum (LINNÉ)

Plate 15, figures 3a - b
B.M. no. 1969:4:30:88

'Cornu Hammonis orbiculatum' Plancus 1739: Conchyliologia mineralogica p. 10, pl. 1, fig. 2.

'Nautilus minimus' Gualtieri 1742: Index Testaceorum Conchyliologiae pl. 19, figs. A, D.

Nautilus crispus Linnaeus 1758: Systema Naturae Ed. 10, p. 709, Ed. 13, (Gmelin's) p. 3370, 1788.

Polystomella crispa (Linné) Lamarck 1822: Histoire des animaux sans vertebres, vol. 7, p. 625.

Elphidium crispum (Linné) Cushman & Grant 1927: San Diego Soc. Nat. History Trans. vol. 5, no. 6, p. 73, pl. 7, figs. 3a - b.

Description: Test free, planispiral, involute, biumbonate, compressed, umbilical regions slightly raised with a medium sized rounded boss of clear shell material, surface of this often studded with a number of small, shallow, rounded pits; periphery acute, slightly keeled; chambers long, narrow, 15 - 20 in adult whorl, increasing in size gradually as added; sutures distinct, broad and somewhat sigmoid, umbilical ends being almost radial and later curving back towards periphery; up to 10 prominent retral processes per chamber, extending well up onto side of succeeding chambers; aperture a row of pores at base of apertural face of final chamber; wall calcareous, hyaline, finely perforate, radial in structure; dimensions of hypotype: max. diameter 0.85 mm., min. diameter 0.78 mm., thickness 0.40 mm.

Remarks: The type specimen of E. crispum appears to have been lost, and Linnaeus did not give a type figure but referred to the figures of Plancus and Gualtieri. Both these figures do not provide a great deal of detail but Ebro delta specimens agree well with specimens from Rimini, from where both Plancus and Gualtieri collected their specimens.

Elphidium excavatum (TERQUEM)

Plate 15, figure 4

B.M. no. 1969:4:30:89

Polystomella excavata Terquem 1875: Essai sur le classement des animaux qui vivent sur le plage et dans les environs de Dunkerque. Premier fascicule. Paris p. 20, pl. 2, figs. 2a - b.

Elphidium c.f. E. flexuosum (D'ORBIGNY)

Plate 16, figures 1a - b
B.M. no. 1969:4:30:90

Polystomella flexuosa d'Orbigny 1846: Foraminifères fossiles du bassin tertiare de Vienne. Gide et Comp. Paris p. 127, pl. 6, figs. 15 - 16.
Elphidium groenlandicum (Cushman) Kruit 1955: Sediments of the Rhône delta. Mouton & Co. p. 114, pl. 2, fig. 12.

Description: Test free, planispiral, involute, somewhat compressed, biumbonate; periphery acute with a narrow keel; chambers 12 - 15 in final whorl, slightly inflated, especially the later ones; sutures distinct, slightly depressed, curved; retral processes about 10 to the adult; umbonal bosses raised and composed of clear shell material; aperture a row of pores along base of apertural face of final chamber; wall smooth, calcareous, hyaline, finely perforate, radial in structure; dimensions of hypotype: max. diameter 0.56 mm., min. diameter 0.48 mm., thickness 0.28 mm.

Elphidium incertum (WILLIAMSON)

Plate 16, figure 2
B.M. no. 1969:4:30:91

Polystomella umbilicatula Walker var. incerta Williamson 1858:

On the Recent Foraminifera of Great Britain. Ray Soc. p. 44, pl. 3, fig. 82.

Elphidium incertum (Williamson) Cushman 1930: U.S. Nat. Mus. Bull. 104, pt. 7, p. 18, pl. 7, figs. 4 - 9.

Description: Test free, planispiral, involute, compressed; chambers slightly inflated, 8 in the final whorl; sutures distinct, depressed and curved; distinct retral processes, about 4 or 5 per chamber; umbilici slightly depressed; aperture a narrow slit at base of apertural face of final chamber; wall calcareous, hyaline, finely perforate, granular in structure; dimensions of hypotype: max. diameter 0.32 mm., min. diameter 0.26 mm., thickness 0.10 mm.

Remarks: Ebro delta specimens agree well with the lectotype of E. incertum mounted by Loeblich from Williamson's syntypes in the British Museum (slide no. 1955:3:30:2, ex. 96:8:13:16). However, the generic position of the Ebro specimens is unsatisfactory. Inclusion within the genus Elphidium is on the basis of the retral processes, but the species has a granular wall structure which means that it should strictly be placed within the Cassidulinacea and not the Rotaliacea, according to Loeblich and Tappan's classification. Other authors have also noted the discrepancy of species with retral processes having granular wall structures.

Elphidium lidöense CUSHMAN

Plate 16, figure 3
B.M. no. 1969:4:30:92

Cushman 1936: Some new species of Elphidium and related genera.
Cushman Lab. Foram. Res. Contr. vol. 12, pt. 4, p. 86, pl. 15, figs. 6a - b.

Description: Test free, planispiral, compressed, involute; periphery

rounded; chambers slightly inflated, about 10 in the adult whorl, increasing gradually in size as added; sutures distinct, depressed, slightly curved and broadening towards the umbilicus; retral processes very small, indistinct; umbilici large with several distinct, rounded bosses of smooth shell material; aperture a row of pores along base of apertural face of final chamber; wall calcareous, hyaline, coarsely perforate except for apertural face, radial in structure; dimensions of hypotype: max. diameter 0.30 mm., min. diameter 0.25 mm., thickness 0.14 mm.

Remarks: Ebro delta specimens are identical with Cushman's type figures and also with specimens collected close to his type locality near Venice Lido.

Elphidium oceanense (D'ORBIGNY)

Plate 16, figure 4
B.M. no. 1969:4:30:93

Polystomella oceanensis d'Orbigny 1826: Tableau méthodique de la classe des cephalopodes.
Ann. Sci. Nat. Paris ser. 1, tome 7, p. 285, no. 8.

Elphidium c.f. E. schmittii CUSHMAN & WICKENDEN

Plate 16, figure 5
B.M. no. 1969:4:30:94

Cushman & Wickenden 1929: Recent Foraminifera off Juan Fernandez Islands.
U.S. Nat. Mus. Proc. Washington vol. 75, no. 2780, p. 7, pl. 3, figs. 9a - c.

Elphidium selseyensis (HERON - ALLEN & EARLAND)

Plate 16, figure 6
B.M. no. 1969:4:30:95

Polystomella striatopunctata (Fichtel & Moll) var. Heron - Allen & Earland 1909: Roy. Micr. Soc. Jour. p. 695, pl. 21, figs. 2a - c.

Polystomella striatopunctata (Fichtel & Moll) var. selseyensis Heron - Allen & Earland 1911: Roy. Micr. Soc. Jour. p. 448.

Elphidium selseyensis (Heron - Allen & Earland) Cushman 1939: U.S. Geol. Surv. Prof. Paper 191, p. 59, pl. 16, figs. 26 - 28.

Description: Test free, planispiral, involute, compressed; chambers slightly inflated, 10 - 12 in final whorl, increasing gradually in size as added; periphery broadly rounded and may be somewhat lobulate when chambers are more inflated; retral processes short and may be indistinct; umbilici flush or slightly depressed, may be quite large, but always filled with granular material; aperture a row of pores at base of septal face of final chamber; wall calcareous, hyaline, conspicuously perforate, radial in structure, frequently transparent; dimensions of hypotype: max. diameter 0.42 mm., min. diameter 0.36 mm., thickness 0.19 mm.

Remarks: The type specimens of this species could not be found in the British Museum, but Ebro delta specimens agree well with specimens collected from Selsey Bill (Heron - Allen and Earland's type locality).

Elphidium sp. 1

Plate 16, figure 7
B.M. no. 1969:4:30:96

Description: Test free, planispiral, involute, biumbonate, compressed; periphery rounded to subacute; chambers not inflated, increasing very little in size as added, 8 - 10 in final whorl of adult specimen; sutures distinct, gently curved, usually flush, thickening appreciably towards umbilicus; retral processes small and indistinct, about 5 to the adult chamber; umbilici large, flush or slightly raised; filled with clear shell material; aperture a row of pores at base of apertural face of final chamber; wall calcareous, hyaline, distinctly perforate apart from apertural face; dimensions of hypotype: max. diameter 0.27 mm., min. diameter 0.22 mm., thickness 0.14 mm.
Remarks: Although the typical forms are quite distinct, there are many individuals intermediate between this species and E. selseyensis that are difficult to assign to one species or the other. Typically, however, E. sp. 1 has sutures that thicken towards the umbilicus, a more acute periphery and raised umbilici, while E. selseyensis is larger, with more chambers and larger, depressed umbilici.

Elphidium sp. 2

Plate 16, figure 8
B.M. no. 1969:4:30:97

Protelphidium anglicum MURRAY

Plate 17, figure 1
B.M. no. 1969:4:30:98

Nonionina crassula (Walker) Williamson 1858: On the Recent Foraminifera of Great Britain. Ray Soc. p. 33, pl. 3, figs. 70 - 71.
Nonionina depressula (Walker & Jacob) Brady 1884: Challenger Repts. Zool. vol. 19, p. 725, pl. 109, figs. 6a - b.

Protelphidium anglicum Murray 1965: Contr. Cushman Found. Foram. Res. vol. 16, pt. 4, p. 148 - 150.

Description: Test free, planispiral, involute; chambers usually 7 - 9 in final whorl in adult specimen, later ones become slightly inflated; sutures distinct, curved, depressed and filled with granular shell material that sometimes extends into umbilical parts of sutures; aperture a series of pores along base of apertural face of final chamber; wall calcareous, hyaline, finely perforate, radial in structure; dimensions of hypotype: max. diameter 0.29 mm., min. diameter 0.24 mm., thickness 0.12 mm.

Remarks: Ebro delta specimens agree satisfactorily with the holotype deposited in the British Museum (slide 1962:2:12:230).

Superfamily GLOBIGERINACEA Carpenter, Parker & Jones 1862

Family Globigeriniidae Carpenter, Parker and Jones 1862

Globigerina bulloides D'ORBIGNY **

Plate 17, figures 2a - b
B.M. no. 1969:4:30:99

d'Orbigny 1826: Tableau méthodique de la classe des cephalopodes.
Ann. Sci. Nat. Paris ser. 1, tome 7, p. 277, no. 1, Modeles no. 76, no. 17.

Globigerina inflata D'ORBIGNY **

Plate 17, figure 3
B.M. no. 1969:4:30:100

d'Orbigny 1839: In - Barker - Webb and Berthelot, Histoire Nat. Iles Canaries, vol. 2, pt. 2, 'Foraminifères', p. 134, pl. 2, figs. 7 - 9.

Globigerina pachyderma (EHRENBERG) **

Plate 17, figure 4
B.M. no. 1969:4:30:101

Aristerospira pachyderma Ehrenberg 1861: Monats. K. preuss Ak. Wiss. Berlin p. 303.

Globigerina quinqueloba NATLAND **

Plate 17, figures 5a - b
B.M. no. 1969:4:30:102

Natland 1938: Bull. Scripps Inst. Oceanogr. Tech. Ser. vol. 4, no. 5, p. 149, pl. 6, figs. 7a-c.

Superfamily ORBITOIDACEA Schwager 1876

Family Eponididae Hofker 1951

Eponides granulata DI NAPOLI ALLIATA

Plate 18, figures 1a - b
B.M. no. 1969:4:30:103

Eponides frigidus Cushman var. granulatus di Napoli Alliata 1952: Riv. Ital. Pal. Strat. vol. 58, no. 3, p. 9,

pl.5, figs. 3a - b.

Rotalia faramanensis Kruit 1955: Sediments of the Rhône delta. Mouton & Co. p. 116, pl. 2, figs. 16 a-c.

Rotalia granulata (di Napoli Alliata) Parker 1958: Repts. Swedish Deep Sea Exped. vol. 8, p. 269, pl. 4, figs. 1 - 2.

Description: Test free, trochoid, biconvex, subcircular in outline or slightly lobulate; periphery acute; chambers very slightly inflated on dorsal side, more so on ventral side, 6 - 8 in final whorl, 3 - 4 whorls in adult specimen, all chambers visible from sprial dorsal side, only those of final whorl visible ventrally; sutures distinct, on dorsal side flush or very slightly depressed, slightly curved and strongly oblique, on ventral side slightly depressed, slightly curved and nearer radial; umbilical region on ventral side large and filled with granular deposits that extend a little into umbilical region of sutures; dorsal surface of test smooth; aperture narrow, interiomarginal, midway between umbilicus and periphery on ventral side; wall calcareous, hyaline, perforate, radial in structure; dimensions of hypotype: max. diameter 0.36 mm., min. diameter 0.33 mm., thickness 0.18 mm.

Poroeponides lateralis (TERQUEM)

Plate 18, figures 2a - b
B.M. no. 1969:4:30:104

Rosalina lateralis Terquem 1878: Les foraminifères et les entromostraces ostracodes du Pliocene superieur de l'Ile de Rhodes.
Soc. Geol. France Mem. ser. 3, tome 1, no. 3, p. 25, pl. 2, figs. 11 a - c.

Family Cibicididae Cushman 1927

Planulina ariminensis D'ORBIGNY

Plate 18, figure 3
B.M. no. 1969:4:30:105

A. d'Orbigny 1826: Tableau méthodique de la classe des cephalopodes.
Ann. Sci. Nat. Paris ser. 1, tome 7, p. 280, pl. 14, figs. 1 - 3.

Cibicides c.f. C. bradii TOLMACHOFF

Plate 18, figure 4
B.M. no. 1969:4:30:106

I.P. Tolmachoff 1934: A Miocene microfauna and flora from the Atrato River, Columbia, South America.
Carnegie Mus. Ann. vol. 23, p. 233, pl. 19, figs. 1a - b.

Cibicides lobatulus (WALKER & JACOB) **

Plate 19, figures 1a - b
B.M. no. 1969:4:30:107

Nautilus lobatulus Walker & Jacob 1798: In - Kanmacher, 'Adam's essays on the microscope' Ed. 2, p. 642, pl. 14, fig. 36.

Family Planorbulinidae d'Orbigny 1826

Planorbulina mediterranensis D'ORBIGNY

Plate 19, figure 2
B.M. no. 1969:4:30:108

A. d'Orbigny 1826: Tableau méthodique de la classe des cephalopodes.
Ann. Sci. Nat. Paris ser. 1, tome 7, p. 280, pl. 14, figs. 4 - 6.

Superfamily CASSIDULINACEA d'Orbigny 1839

Family Caucasinidae Bykova 1959

Fursenkoina c.f. F. complanata (EGGER)

Plate 19, figure 3
B.M. no. 1969:4:30:109

Virgulina schreibersiana Czjek var. complanata Egger 1893: Abhandl. kon. bay. Wiss. Munchen Cl. III, vol. 18, p. 292, pl. 8, figs. 91 - 92.
Virgulina subsquammosa Cushman (non Egger) 1924: Publ. 342 Carnegie Inst. Washington, p. 26,
Virgulina complanata (Egger) Cushman 1937: Cushman Lab. Foram. Res. Spec. Publ. no. 9, p. 26, pl. 4, figs. 13 - 17.

Description: Test free, narrow, elongate, 4 - 6 times as long as broad; chambers numerous, increasing rapidly in size as added giving

a flared appearance to test, inflated, greater in height than breadth, in early portion a twisted biserial arrangement later becoming more typically biserial; short spine on initial end; sutures distinct, depressed; apertures large, ovate, extending up apertural face of final chamber, with slight lip on one side and toothplate bending over into aperture on opposite side; wall calcareous, hyaline, finely perforate, granular in structure; dimensions of hypotype: length 0.40 mm., max. diameter 0.12 mm.

Fursenkoina schreibersiana (CZJZEK)

Plate 19, figure 4
B.M. no. 1969:4:30:110

Virgulina schreibersiana Czjzek 1848: Haidinger's Abhandl. Nat. vol. 2, p. 11, figs. 18 - 21.
Virgulina squammosa (d'Orbigny) Egger 1895: Jahresb. XVI Nathist. Ver. Passau p. 18, pl. 1, figs. 21a - c.

Description: Test free, elongate, somewhat fusiform, early portion twisted biserial, later part biserial but irregular, chambers on one side may be slightly higher than the other; periphery rounded; chambers elongate, slightly inflated, increasing in size as added; sutures distinct, oblique, depressed; aperture narrow, elongate, extending up face of final chamber; wall calcareous, hyaline, finely perforate, granular in structure; dimensions of hypotype: length 0.31 mm., max. diameter 0.17 mm.

Fursenkoina sp.

Plate 19, figure 5
B.M. no. 1969:4:30;111

Family Delosinidae Parr 1950

Delosina complexa (SIDEBOTTOM)

Plate 19, figure 6
B.M. no. 1969:4:30:112

Polymorphina (?) complexa Sidebottom 1907: Report on the Recent Foraminifera from the coast of the Island of Delos (Grecian Archipelago). Pt. 4. Manchester Lit. & Phil. Soc. Mem. & Proc. vol. 51, no. 9, p. 16.

Family Cassidulinidae d'Orbigny

Cassidulina laevigata D'ORBIGNY

Plate 19, figure 7
B.M. no. 1969:4:30:113

A. d'Orbigny 1826: Tableau méthodique de la classe des cephalopodes.
Ann. Sci. Nat. Paris ser. 1, tome 7, pl. 15, figs. 4 - 5

Description: Test free, lenticular, biumbonate with clear central bosses; periphery acute with narrow keel; chambers elongate, curved, rarely very slightly inflated, arranged biserially in a coil, alternating on either side of periphery, each reaching central boss on one side and only part of way to boss on opposite side; sutures distinct, slightly limbate; aperture an elongate slit extending up from base of final chamber parallel to anterior margin of

chamber; wall calcareous, hyaline, perforate, granular in structure; dimensions of hypotype: max. diameter 0.23 mm., min. diameter 0.19 mm., thickness 0.12 mm.

Cassidulina c.f. crassa D'ORBIGNY

Plate 19, figure 8
B.M. no. 1969:4:30:114

A. d'Orbigny 1839: Voyage dans l'Amerique Meridionale. Foraminifères. Levrault, Strasbourg, tome 5, pt. 5, p. 56, pl. 7, figs. 18 - 20.

Globocassidulina sp. **

Plate 19, figure 9
B.M. no. 1969:4:30:115

Family Nonionidae Schultze 1854

Nonion asterizans (FICHTEL & MOLL)

Plate 20, figures 1a - b
B.M. no. 1969:4:30:116

Nautilus asterizans Fichtel & Moll 1798: Testacea microscopia. p. 37, pl. 3, figs. e - h.
Nonionina asterizans (Fichtel & Moll) Sidebottom 1910: Manchester Lit. & Phil. Soc. Mem. & Proc. vol. 54, pt. 16.
Nonion asterizans (Fichtel & Moll) Kruit 1955: Sediments

of the Rhône delta. Mouton & Co. p. 113, pl. 11, figs. 7a - b.

Description: Test free, planispiral, involute, compressed; chambers 9 - 12 in final whorl, slightly inflated and increasing only very little in size as added; periphery subacute; sutures distinct, depressed, curved; umbilici small, very slightly depressed; aperture a row of pores along base of apertural face of final chamber, also secondary sutural apertures (especially in larger specimens) which are narrow, elongate slits along rear edge of chambers; wall calcareous, hyaline, finely perforate, granular in structure; dimensions of hypotype: max. diameter 0.44 mm., 0.36 mm., thickness 0.18 mm. Remarks: There has been a great deal of confusion in the past over the identification of this species, and many authors have illustrated species which do not bear a close relation to Fichtel & Moll's original figures. Although the type figures are not good they do show that the original had 12 chambers, with curved sutures, that only increase gradually in size as added. However, 'topotypes' figured by Cushman (1946) have chambers that increase rapidly in size, and larger umbilici, rather like a Florilus. Many of the species in the Recent Foraminifera collection of the British Museum labelled as N. asterizans should correctly be referred to other species. Ebro delta specimens are identical with specimens from the type locality at Rimini and are much closer to Fichtel & Moll's type figures.

Nonion depressulus WALKER & JACOB emend. MURRAY

Plate 20, figure 2
B.M. no. 1969:4:30:117

"Nautilus spiralis utrinque...." Walker & Boys 1784: Testacea minuta rariora; p. 19, fig. 68.

Nautilus depressulus Walker & Jacob 1798: In - Kanmacher 'Adam's essays on the microscope', p.641, pl.14, fig. 33.

Nonion depressulus (Walker & Jacob) Murray 1965: Contr. Cushman Found. Foram Res. vol. 16, pt. 4, p. 148 - 150.

Description: Test free, planispiral, involute, compressed; chambers 9 or 10 in final whorl, increasing in size as added, slightly inflated; sutures distinct, depressed, more so towards umbilicus, curved; umbilici depressed, filled with granular material which extends into umbilical areas of sutures; aperture a row of pores along base of apertural face of final chamber; wall transparent, calcareous, hyaline, finely perforate, granular in structure; dimensions of hypotype: max. diameter 0.26 mm., min. diameter 0.21 mm., thickness 0.09 mm.

Remarks: The Ebro delta specimens agree reasonably well with topotypes collected from Reculver (see Murray 1965b), although some tend to be a little more compressed.

Nonion c.f. N. germanicum (EHRENBERG)

Plate 20, figure 3
B.M. no. 1969:4:30:118

Nonionina germanica Ehrenberg 1840: K. Preuss. Akad. Wiss. Berlin p. 23.
Type figure: Ehrenberg 1841: K. Akad. Wiss Berlin, Physik - Math. Kl., Abl. Jahrg. 1839 pl. 2, fig. 1.

Nonion germanicum (Ehrenberg) Cushman 1930: U.S. Nat. Mus. Bull. vol. 104, pt. 7, p. 8, pl. 3, figs. 4 - 5.

Description: Test free, planispiral, involute, compressed; chambers about 9 in final whorl of adult specimen, increasing only very

slightly in size as added, slightly inflated; sutures distinct, curved depressed, becoming thicker and more depressed towards the umbilicus; umbilici filled with granular material that frequently extends into umbilical region of sutures; aperture a very narrow slit at base of apertural face of final chamber; wall calcareous, hyaline, finely perforate, granular in structure; dimensions of hypotype: max. diameter 0.28 mm., min. diameter 0.24 mm., thickness 0.11 mm.

Nonion laevigatum (D'ORBIGNY)

Plate 20, figure 4
B.M. no. 1969:4:30:119

Nonionina laevigata A. d'Orbigny 1826: Tableau méthodique de la classe des cephalopodes.
Ann. Sci. Nat. Paris ser. 1, tome 7, p. 293.
Also - F.E. Guerin - Meneille - Iconographie de Regne Animal de G. Cuvier.
J.B. Bailliere, Paris, 1843. Mollusques, p. 9, pl. 2, fig. 7.
Fornasini 1899: Accad. Sci. Ist. Bologna Mem. Ser. 5a, vol. 7, p. 13, text fig. 1; 1900 vol. 8, p. 43, fig. 47.

Description: Test free, planispiral, involute, compressed; chambers 5 - 7 in final whorl, inflated, increasing in size as added; sutures distinct, sharply recurved, depressed, especially in umbilical region; umbilici depressed and filled with granular material that sometimes extends into umbilical region of sutures; aperture obscure, but is probably a very small slit or row of pores at base of apertural face of final chamber; wall calcareous, hyaline, very finely perforate, granular in structure; dimensions of hypotype: max. diameter 0.20 mm., min. diameter 0.16 mm., thickness 0.08 mm.

Nonion matagordanum KORNFELD

Plate 20, figure 5
B.M. no. 1969:4:30:120

Nonion depressula Walker & Jacob var. matagordana Kornfeld 1931: Recent littoral Foraminifera from Texas and Louisiana.
Stanford Univ. Dept. Geol. Contr. vol. 1, p.87, pl. 13, fig. 2.

Florilus scaphus (FICHTEL & MOLL)

Plate 21, figure 1
B.M. no. 1969:4:30:121

Nautilus scapha Fichtel & Moll 1798: Testacea microscopia p. 105, pl. 19, figs. d - f.
Nonionina scapha (Fichtel & Moll) Brady 1865: Nat. History Trans. Northumberland & Durham vol. 1, p. 106, pl. 12, figs. 10a - b.
Nonion scaphum (Fichtel & Moll) Cushman 1930: U.S. Nat. Mus. Bull. 104, pt. 7, p. 5, pl. 2, figs. 3 - 4.

Description: Test free, planispiral, involute, slightly compressed; periphery subacute; chambers 12 - 16 in final whorl of adult specimen, increasing in size as added, resulting in flaring of test; sutures distinct, gently curved, slightly depressed in umbilical region only; umbilici slightly depressed, filled with white granular material that often extends into umbilical regions of sutures; aperture a narrow, equatorial, interiomarginal slit; wall calcareous, hyaline, finely perforate, granular in structure; dimensions of hypotype: max. diameter 0.56 mm., min. diameter 0.40 mm, thickness 0.21 mm.

Remarks: Fichtel and Moll's type specimens were collected from Rimini, and they also recorded it from the Pliocene of the Sienna region of Italy. Although the type figures are not good, they do show that the test appears to 'flare', having a greater height than breadth. Ebro delta specimens agree satisfactorily with the type figures and also with specimens collected near the type localities.

Florilus c.f. F. japonicum (ASANO)

Plate 21, figure 2
B.M. no. 1969:4:30:122

Nonion japonicum Asano 1938: On the Japanese species of Nonion and its allied genera.
Geol. Soc. Japan Jour. vol. 45, no. 538, p. 593, pl. 15, figs. 1 - 2.

Nonionella atlantica CUSHMAN

Plate 21, figure 3
B.M. no. 1969:4:30:123

Cushman 1947: New species of Foraminifera from off the southeast coast of the United States.
Contr. Cushman Lab. Foram. Res. vol. 23, p. 90, pl. 12, fig. 3.

Nonionella opima CUSHMAN

Plate 21, figures 4a - c
B.M. no. 1969:4:30:124

Cushman 1947: New species of Foraminifera from off the southeast coast of the United States.
Contr. Cushman Lab. Foram. Res. vol. 23, p. 90, pl. 20, figs. 4 - 5.

Description: Test free, trochospiral, asymmetrical, spiral side evolute with an umbonal boss; chambers 6 - 10, increasing rapidly in size as added, final chamber very inflated and extends to umbilical side to form prominent umbilical flap; periphery rounded; sutures distinct, straight, flush or very slightly depressed; aperture interiomarginal, a low arch extending a little onto umbilical side; wall calcareous, hyaline, very finely perforate, granular in structure; dimensions of hypotype: length 0.31 mm., width 0.21 mm., thickness 0.18 mm.

Family Alabaminidae Hofker 1951

Gyroidina c.f. G. umbonata (SILVESTRI) **

Plate 22, figures 1a - c
B.M. no. 1969:4:30:125

Rotalia soldanii d'Orbigny var. umbonata Silvestri 1898: Mem. Accad. Pont. Nuovi Lincei, vol. 15, p. 329, pl. 6, figs. 14a - c.

Family Anomalinidae Cushman 1927

Melonis pompilioides (FICHTEL & MOLL)

Plate 22, figure 2
B.M. no. 1969:4:30:126

Nautilus pompilioides Fichtel & Moll 1798: Testacea microscopia p. 31, pl. 2, figs. a - c.

Superfamily ROBERTINACEA Reuss 1850

Family Robertinidae Reuss 1850

Robertina arctica D'ORBIGNY emend. HÖGLUND

Plate 22, figure 3
B.M. no. 1969:4:30:127

d'Orbigny 1846: Foraminifères fossiles du bassin tertiare de Vienne.
Gide et Comp. Paris p. 202, pl. 21, figs. 37 - 38.
Höglund 1947: Foraminifera of the Gullmar Fjord and the Skagerak.
Uppsala Univ. Zool. Bidrag Bd. p. 219, pl. 18, fig. 2.

LIST OF REFERENCES

ADAMS C.S., 1967

Tertiary Foraminifera in the Tethyan, American and Indo - Pacific provinces. Syst. Assoc. Publ. no 7, pp. 195 - 217.

ALLEN J.R.L., 1965

Late Quaternary Niger delta and adjacent seas, sedimentary environments and lithofacies. Amer. Assoc. Petroleum Geologists Bull. vol. 49, pp. 547 - 602.

ARNOLD Z.M., 1954

Culture methods in the study of living Foraminifera. Jour. Paleont. vol. 28, 404 p.

BANDY O.L., 1953

Ecology and paleoecology of some California Foraminifera. Jour. Paleont. vol. 27, Pt. I pp. 161 - 182, Pt. II 200 - 203.

——— , 1954

Distribution of some shallow water foraminiferids in the Gulf of Mexico. U.S. Geol. Surv. Prof. Paper 254F.

BANDY O.L. & CHIERICI M.A., 1966

Depth/temperature evaluation of selected bathyal Foraminifera common to California and the Mediterranean. Marine Geol. vol. 4, pp. 259 - 271.

BANDY O.L., INGLE J.C. & RESIG J.M., 1965

Facies trends, Hyperion Outfall, California. Limnol. & Oceanogr. vol. 10, pt. 3, p. 314.

BARRACLOUGH - FELL H., 1967

Cretaceous and Tertiary surface currents of the oceans. In H. Barnes Ed., Oceanography and Marine Biology, vol. 5, pp. 317 - 343.

BARTLETT G.A., 1965

Preliminary investigation of benthonic foraminiferal ecology in Tracadie Bay, Prince Edward Island. Report B.I.O. 65-3, Bedford Inst. Oceanography.

———— , 1968

Planktonic Foraminifera, a new dimension with the scanning electron microscope. Canadian Jour. Sci. vol. 5, pt. 2, pp. 231 - 233.

BATES C.C., 1953

Rational theory of delta formation. American Assoc. Petroleum Geologists Bull. vol. 37, p. 2119.

BÉ A.W.H. & HAMLIN W.H., 1967

Ecology of Recent planktonic Foraminifera; Pt. 3 - Distribution in the North Atlantic during the summer of 1962. Micropaleont. vol. 13, no. 1, p. 87.

BLANC J.J., 1969

Sedimentary geology of the Mediterranean Sea. In H. Barnes Ed., Oceanography and Marine Biology, vol. 6, pp. 377 - 455.

BLANC - VERNET L., 1958

Les milieux sedimentaires littoraux de la Provence occidentale (côte rocheuse). Relations entre la microfaune et la granulometrie du sediment. Bull. Mus. Oceanogr. Monaco no. 1112.

———————— , 1963

Note preliminaire sur les foraminifères des fonds Détritiques Côtiers et de la Vase Terrigene Côtiers dans la baie de Marseille. Rév. Trav. mar. Endoume, no. 45, pp. 83 - 93.

BOLTOVSKOY E., 1956

Applications of chemical ecology in the study of Foraminifera. Micropaleont. vol. 2, p. 321.

———————— , 1965

Los Foraminiferos Recientes. Editorial Universiteria de Buenos Aires.

———————— , 1966

The depth at which Foraminifera can survive in sediments. Cushman Found. Foram Res. Contr. vol. 17, pt. 2, p. 43.

———————— , 1969

Living planktonic Foraminifera at the 90° east meridian from the Equator to the Antarctic. Micropaleont. vol. 15, no. 2, pp. 237 - 255.

BONHAM - CARTER G., 1968

Fortran IV program from Q-mode cluster analysis of non - quantitative data using IBM 7090/7094 computers. Computer Contr. 17, State Geol. Survey, Univ. Kansas.

BOTTERON G., 1958

Étude de sediments recoltés au cours de plongées avec le bathyscaphe 'Trieste' au large de Capri. Bull. Labs. Univ. Lausanne, no. 124, pp. 1 - 20.

BOUGIS P., GINAT M. & RUIVO M., 1957

Contribution a l'hydrologie de la Mer Catalane. Resultat des campagnes du 'Professeur Lacaze - Duthiers'. Vie et Milieu Suppl. no. 6, pp. 123 - 164.

BRADSHAW J.S., 1955

Preliminary experiments on the ecology of foraminiferal populations. Micropaleont. vol. 1, pp. 351 - 358.

———— , 1957

Laboratory studies on the foraminifer Streblus beccarii (Linné) var. tepida Cushman. Jour. Paleont. vol. 31, p. 1138.

———— , 1961

Laboratory experiments on the ecology of Foraminifera. Cushman Found. Foram. Res. Contr. vol. 12, pp. 87 - 106.

BROOKS A.L., 1967

Standing crop, vertical distribution and morphometrics of Ammonia beccarii (Linné).

BUZAS M., 1965

The distribution and abundance of Foraminifera in Long Island Sound. Smithsonian Misc. Coll. vol. 149, no. 1, pp. 1 - 86.

BUZAS M. & GIBSON T., 1969

Species diversity: Benthic Foraminifera in the western Atlantic. Science vol. 163, pp. 72 - 75.

CLOSS D., 1963

Foraminiferos e tecamoebas da Lagoa dos Patos, Rio Grande do Sul. Univ. Esc. Geol. Porto Alegre, Bol. no. 11 (1962) pp. 1 - 130.

COLOM G., 1952

Foraminiferos de als costas de Galicia (Portugal). Bol. Inst. Espanol de Oceanographia, no. 51.

——— , 1963

Los foraminiferos de la Ria de Vigo. Investigacion Pesq. vol. 23, pp. 71 - 89.

CURRY D., MURRAY J.W. & WHITTARD W.F., 1965

The geology of the Western Approaches of the English Channel. III, The Globigerina Silts and Associated Rocks. In, Whittard and Bradshaw, Eds., Submarine Geology and Geophysics, 17th Colston Symposium; Butterworths, London.

CUSHMAN J.A., 1939

A monograph of the Foraminiferal family Nonionidae. U.S. Geol. Surv. Prof. Paper 191.

——— , 1945

The species of Foraminifera recorded by d'Orbigny in 1826 from the Pliocene of Castel Arquato, Italy. Cushman Lab. Foram. Res. Spec. Publ. 13.

——— , 1946

The species of Foraminifera named and figured by Fichtel and Moll in 1798 and 1803. Cushman Lab. Foram. Res. Spec. Publ. 17.

CUSHMAN J.A., 1949

Recent Belgian Foraminifera. Mem. Inst. Roy. Sci. Nat. Belg. no. 111.

DENNISON J.M. & HAY W.H., 1967

Estimating the needed sampling area for subaquatic ecologic studies. Jour. Paleont. vol. 41, no. 3, pp. 706 - 708.

DOBBY E.H.G., 1936

The Ebro delta. Geographical Journal vol. 87, pp. 455 - 474.

DRYDEN A.L., 1931

Accuracy in percentage representation of heavy mineral frequencies. Proc. Natl. Acad. Sci. vol. 17, pp. 233 - 238.

EKMAN G., 1953

Zoogeography of the sea. MacMillan.

ELLIS & MESSINA A., 1948 et seq.

Catalogue of Foraminifera (Microfilm Edn.) American Museum of Natural History.

EMILIANI C., 1955

Pleistocene temperature variations in the Mediterranean. Quaternaria vol. 2, pp. 87 - 98.

EMILIANI C., MAYEDA T. & SELLI R., 1961

Paleotemperature analysis of the Plio - Pleistocene section at Le Castella, Calabria, southern Italy. Geol. Soc. America Bull. vol. 72, no. 5, pp. 679 - 688.

ERIKSSON K.G., 1961

The sediment core no. 210 from the western Mediterranean. Repts. from the Swedish Deep Sea Expedition vol. 8, p. 396.

FEHLING - HANSEN R.F., 1954

Late Pleistocene foraminifera from the Oslo Fjord area, southeastern Norway. Norsk. Geol. Tidsskr. vol. 33, pp. 109 - 152.

FISHER R.A., CORBETT A.S. & WILLIAMS C.B., 1943

The relation between the number of species and the number of individuals in a random sample of an animal population. J. anim. Ecol. vol. 12, pp. 42 - 58.

GEOGRAPHIA DE CATALUNYA, 1958

Ed. Aedos, Barcelona.

GIBSON L.B., 1966

Some unifying characteristics of species diversity. Cushman Found. Foram. Res. vol. 17, pt. 4, p. 117.

HAAKE F.W., 1967

The annual changes in the population of a foraminiferid species in the Western Baltic. Meyniana vol. 17, pp. 13 - 27.

HOGLUND H., 1947

Foraminifera in the Gullmar Fjord and the Skagerak. Zool. Bidrag. Uppsala, vol. 26, pp. 1 - 328.

HONJO S. & BERGGREN, 1967

Scanning electron studies of planktonic Foraminifera. Micropaleont. vol. 13, no. 4, pp. 393 - 406.

JONKER F.P., 1952

Analyse pollinique d'une tourbière dans le delta de l'Ebre. Collectanea Botanica, III, vol. 2, pt. 5, pp. 170 - 182.

KAESLER R.L., 1966

Quantitative re - evaluation of the ecology and distribution of Recent foraminifera and ostracods in Todos Santos Bay, California. Univ. Kansas Paleont. Contr. Paper 10.

KOLB C. & VAN LOPIK J., 1966

Depositional environments of the Mississippi River deltaic plain, southeastern Louisiana. In, M.L. Shirley Ed., Deltas, Houston Geol. Soc. Publ. pp. 17 - 62.

KRUIT C., 1955

Sediments of the Rhône delta. Mouton & Co., The Hague.

KURC G., 1961

Foraminifères et Ostracodes de l'étang de Thau. Inst. Pêches Marit. Rév. Trav., vol. 25.

LANKFORD R.R., 1959

Distribution and ecology of Foraminifera from the east Mississippi delta margin. Amer. Assoc. Petroleum Geologists Bull. vol. 43, pp. 2068 - 2099.

LE CALVEZ Y., 1958

Les foraminiferes de la mer Celtique. Inst. Pêches Marit. Rév. Trav. vol. 22, p. 147.

LEE J.J., McENERY M., PIERCE S., FREUDENTHAL H. & MULLER W.A., 1966

Tracer experiments on living Foraminifera. Jour. Protozool. vol. 13, no. 4, p. 659 - 671.

LOEBLICH A. & TAPPAN H., 1964

Treatise on Invert. Paleontology; (C) Protista 2, (1) & (2). Geol. Soc. America, Univ. Kansas Press.

LUTZE G., 1964

Zum Farten rezenter Foraminifera. Meyniana vol. 14, pp. 43 - 47.

LYNTS G.W., 1966

Variation of foraminiferid standing crop over short lateral distances in Buttonwood Sound, Florida Bay. Limnol. & Oceanogr. vol. 11, p. 562.

MACFADYEN W.A., 1932

Foraminifera from the late Pliocene and glacial deposits of East Anglia. Geol. Mag. vol. LXIX, no. 821, pp. 481-497.

———— , 1940

Foraminifera in Boulder Clays from the Wexford coast of Ireland. Geol. Mag. vol. LXXVII, pp. 276 - 282.

MARGALEF R., 1963

El ecosistema pelagico de un area costera del mediterraneo occidental. Mem. Real. Acad. Ciencas y Artes Barcelona vol. 35, no. 1.

MARGALEF R. & HERRERA J., 1964

Hidrografia y fitoplancton de las costa comprendida entre Castellon y la desembocadura del Ebro, de julio de 1961 a julio de 1962. Investigacion Pesq. vol. 26, pp. 49 - 90.

MARS P., 1963

Les faunes et la stratigraphie du Quaternaire mediterranean. Rév. Trav. Stn. mar. Endoume vol. 26, pp. 61 - 97.

MARSLAND & BROWN, 1936

Amoeboid movements at high hydrostatic pressure. Jour. Cell & Comp. Physiol. vol. 8, pp. 167 - 177.

MEDITERRANEAN PILOT, 1963 Edn.

MELLO J.F. & BUZAS M.A., 1968

An application of cluster analysis as a method of determining biofacies. Jour. Paleont. vol. 42, p. 747 - 758.

MENARD H.W., SMITH S.M. & PRATT R.M., 1965

The Rhône deep sea fan. In Whittard and Bradshaw, Eds., Submarine Geology and Geophysics, 17th Colston Symposium; Butterworths, London.

MONTCHARMONT - ZEI M., 1964

Studio ecologico sui Foraminiferi del Golfo di Pozuoli (Naples). Pubbl. Staz. Zool. Naples, vol. 34, pp. 160 - 184.

MURRAY J.W., 1961

Ph.D thesis, University of London.

——— , 1962

A new bottom - water sampler for ecologists. Jour. mar. biol. Assoc. U.K., vol. 42, p. 499.

MURRAY J.W., 1965

The significance of benthic foraminiferids in plankton samples. Jour. Paleont. vol. 39, pp. 156 - 159.

——— , 1965a

On the Foraminifera of the Plymouth region. Jour. mar. biol. Assoc. U.K. vol. 45, pp. 481 - 505.

——— , 1965b

Two species of British Recent Foraminifera. Cushman Found. Foram. Res. Contr. vol. 16, pt. 4, p. 148.

——— , 1967

Production in benthonic Foraminifera. Jour. Nat. Hist. vol. 1, pp. 61 - 68.

——— , 1968

Living foraminifers of lagoons and estuaries. Micropaleont. vol. 14, no. 4, pp. 435 - 455.

——— , 1969

Recent foraminifers from the Atlantic Shelf of the U.S.A. Micropaleont. vol. 15, no. 4.

MYERS E.H., 1942

Biological evidence as to the rate at which tests of Foraminifera are contributed to the sediments. Jour. Paleont. vol. 16, pp. 397 - 398.

NICOL J.A.C., 1960

Biology of Marine Animals. Interscience Publishers Inc., New York.

ODUM H.T., CANTLON J.E. & KORNICKER L.S., 1960

An organisational hierarchy postulate for the interpretation of species - individual distributions, species entropy, ecosystem evolution and the measuring of a species variety index. Ecology vol. 41, no. 2, pp. 395 - 399.

OLAUSSON E., 1961

Studies of deep sea cores. Sediment cores from the Mediterranean Sea and the Red Sea. Repts. from the Swedish Deep Sea Expedition vol. 8, p. 337.

ORTON J.H., 1920

Sea temperatures, breeding and distribution in marine animals. Jour. mar. biol. Assoc. U.K. vol. 18, pp. 339 - 366.

PARKER F.L., 1958

Eastern Mediterranean Foraminifera. Repts. from the Swedish Deep Sea Expedition vol. 8, pp. 217 - 283.

PARKER F.L. & ATHEARN W.D., 1959

Ecology of marsh Foraminifera in Poponesset Bay, Massachusetts. Jour. Paleont. vol. 33, pp. 333 - 343.

PARKER F.L., PHLEGER F.B. & PIERSON J.F., 1953

Ecology of Foraminifera from San Antonio Bay and environs, southwestern Texas. Cushman Found. Foram. Res. Spec. Publ. no. 2, p. 75.

PARKER W.K. & JONES T.R., 1860

On the Rhizopodal fauna of the Mediterranean compared with that of the Italian and other Tertiary deposits. Quart. Jour. Geol. Soc. vol. 16, p. 292.

PERES J.M., 1967

Mediterranean benthos. In, H. Barnes Ed., Oceanography and Marine biology, vol. 5, pp. 449 - 533.

PHLEGER F.B., 1951

Displaced foraminiferal faunas in turbidity currents and transport of coarse sediments to deep water. Soc. Econ. Paleon. Min. Spec. Publ. vol. 2, p. 66.

———— , 1952

Foraminiferal ecology off Portsmouth, New Hampshire. Bull. Mus. Comp. Zool. vol. 106, no. 8, pp. 315 - 390.

———— , 1955a

Foraminifera in cores offshore from the Mississippi delta. Deep Sea Research; Papers on Marine Biology and Oceanography, Suppl. to vol. 3, p. 45.

———— , 1955

Ecology of foraminiferids in the southeastern Mississippi delta area. Amer. Assoc. Petroleum Geologists Bull. vol. 39, p. 712.

———— , 1960

Ecology and Distribution of Recent Foraminifera. John Hopkins Press, Baltimore.

———— , 1960a

Foraminiferal populations in Laguna Madre, Texas. Science Repts. Tohoku University, Sendai, Japan, 2 nd. series (Geology), vol. 4.

PHLEGER F.B., 1964

Patterns of living benthonic Foraminifera, Gulf of California. Marine Geology of the Gulf of California, a Symposium, Memoir no. 3, Amer. Assoc. Petroleum Geologists.

PHLEGER F.B. & EWING G.C., 1962

Sedimentology and oceanography of coastal lagoons in Baja California, Mexico. Geol. Soc. America Bull. vol. 73 pp. 145 - 182.

PHLEGER F.B. & LANKFORD R.R., 1957

Seasonal occurrences of living benthonic Foraminifera in some Texas Bays. Cushman Found. Foram. Res. Contr. vol. 8, pt. 3, p. 93.

RAABE E.W., 1952

Uber den 'Affinitatswert' in der Planzensoziologie. Vegetatio, Haag 4, pp. 53 - 68.

RAINWATER E.H., 1966

The geological importance of deltas. In, M.L. Shirley, Ed., Deltas, Houston Geol. Soc. Publ. pp. 1 - 16.

RICHTER G., 1961

Beobachtungen zur Oekologie einiger Foraminiferen des Jade - Gebietes. Natur und Volk vol. 91, pp. 163 - 170.

——— , 1964

Zur Oekologie der Foraminiferen. II Lebensraum und Lebensweise von Nonion depressulum, Elphidium excavatum und Elphidium selseyensis. Natur und Museum vol. 94, pp. 421 - 430.

RUGGIERI G., 1967

The Miocene and later evolution of the Mediterranean Sea. Syst. Assoc. Publ. no. 7, pp. 283 - 290.

RUSCELLI M., 1949

Foraminiferi de due saggi di fondo del Mar Ligure. Atti. Accad. Ligure Sci. Lett. vol. 6, fasc. 1, pp. 347 - 377.

SAID R., 1950

The distribution of Foraminifera in the Red Sea. Cushman Found. Foram. Res. Contr. vol. 1, pp. 9 - 29.

SANDERS H., 1968

Marine benthic diversity: a comparative study. Amer. Naturalist vol. 102, no. 925, pp. 243 - 281.

SANDON H., 1932

The food of Protozoa. Publ. Fac. Sci. Egypt Univ. vol. 1, pp. 1 - 187.

SCHAFER C.T., 1967

Factors influencing the numerical accuracy of benthonic foraminiferal population counts from bottom sediment samples from the Gulf of St. Lawrence. Maritime Seds. vol. 3, p. 71.

SCHLUMBERGER C., 1893

Monographie des Miliolidées du golfe de Marseille. Soc. Zool. France Mem. Paris, tome 6, p. 70.

SCRUTON P.C., 1960

Delta building and the deltaic sequence. In, Recent Sediments, Northwest Gulf of Mexico, American Assoc. Petroleum Geologists Publ. p. 83.

SCRUTON P.C. & MOORE D.G., 1953

Distribution of surface turbidity off the Mississippi delta. Amer. Assoc. Petroleum Geologists Bull. vol. 37, p. 1067.

SELLI R., 1967

Plio/Pleistocene boundary in Italina marine sections and its relationship to Continental stratigraphies. Progress in Oceanography vol. 14, pp. 67 - 88.

SHEPARD F.P., 1960

Mississippi delta: Marginal environments, sediments and growth. In, Recent Sediments, Northwest Gulf of Mexico; Amer. Assoc. Petroleum Geologists Spec. Publ. p. 56.

SHEPARD F.P. & MOORE D.G., 1955

Central Texas coast sedimentation: characteristics of the sedimentary environment, recent history and diagenesis. Amer. Assoc. Petroleum Geologists Bull. vol. 39, pp. 1463 - 1593.

SHIFFLET E., 1961

Living and dead total foraminiferal populations, Heald Bank, Gulf of Mexico. Micropaleont. vol. 7, pp. 45 - 54.

SIDEBOTTOM H., 1910

On the Recent Foraminifera from the Bay of Palermo, Sicily, 14 - 20 fathoms (off the harbour.) Manchester Lit. and Philosoph. Soc. Mem. & Proc. vol. 54, pt. 16.

SILVESTRI A., 1899

Foraminiferi Pliocenici della Provincia di Siena, Parte I. Pont. accad. Sci. Nuovi Lincei Mem. vol. 15, pp. 154 - 381.

SIMPSON E.H., 1949

The measurement of diversity. Nature vol. 163, p. 688.

SOUTHWARD A.J., 1963

Distribution of some plankton animals in the English Channel and approaches. III, Theories about long term biological changes, including fish. J. mar. biol. Assoc. U.K. vol. 43, pp. 1 - 31.

———— , 1967

Recent changes in abundance of intertidal barnacles in Southwest England: a possible effect of climatic deterioration. J. mar. biol. Assoc. U.K. vol. 47, pp. 81 - 96.

SVERDRUP U., JOHNSON M.W. & FLEMING R.H., 1942

The Oceans. Prentice - Hall, New York.

TODD R., 1958

Foraminifera from the western Mediterranean deep sea cores. Repts. from the Swedish Deep Sea Expedition, vol. 8, pp. 167 - 216.

TODD R. & BRONNIMAN P., 1957

Recent Foraminifera and Thecamoebinae from the eastern Gulf of Paria. Cushman Found. Foram. Res. Spec. Publ. no. 3, p. 43.

UCHIO T., 1960

Ecology of living benthonic Foraminifera from the San Diego, California, area. Cushman Found. Foram. Res. Spec. Publ. no. 5, pp. 1 - 72.

VAN STRAATEN L.M.J.U., 1959

Littoral and submarine morphology of the Rhône Delta. Proc. 2nd Coastal Geogr. Conf. Louisiana State Univ., Baton Rouge, p. 233.

———— , 1966

Micro - malacological investigation of cores from the South-east Adriatic Sea. Koninkl. Ned. Akad. Weteschap. Proc. Ser. B vol. 69, pt. 3, pp. 429 - 445.

VAUGHAN T.W., 1933

The biogeographic relations of the Orbitoid Foraminifera. Proc. natn. Acad. Sci. U.S.A. vol. 19, pp. 922 - 938.

VIVES R. & PLANES M., 1952

Publ. Inst. Biol. Apl. Barcelona vol. 11, pp. 141 - 161.

WALTON W.R., 1952

Techniques for the recognition of living Foraminifera. Cushman Found. Foram. Res. Contr. vol. 3, pp. 56 - 60.

——— , 1955

Ecology of living benthonic Foraminifera, Todos Santos Bay, Baja California. Jour. Plaeont. vol. 29, pp. 952 - 1018.

——— , 1964

Recent foraminiferal ecology and paleoecology. In, Imbrie and Newell Eds., Approaches to Paleoecology, pp. 151 - 237.

WARREN A.D., 1957

Foraminifera of the Buras - Schofield Bayou region, southeastern Louisiana. Cushman Found. Foram. Res. Contr. vol. 8, p. 29.

WEISNER H., 1923

Die Miliolideen der östlichen Adria. Prague, 1923.

WILLIAMS C.B., 1964

Patterns in the Balance of Nature. Academic Press, New York.

WILLIAMSON W.C., 1858

On the Recent Foraminifera of Great Britain. Ray Soc. 1858.

WUST G., 1960

Die tiefenzirkulation des mittellandischen Meeres in den Kernschichten des Zwischen und des Tiefenwassers. Deutsche Hydrographische Zeitschrift vol. 13, pp. 105 - 131.

YULE G.U., 1944

The Statistical Study of the Literary Vocabulary. Cambridge University Press.

ZENKOVITCH V.P., 1967

Processes of Coastal Development. Oliver & Boyd, London.

ZEUNER F., 1959

The Pleistocene Period. Hutchinson.

ZOBELL C.F., 1946

Marine Microbiology. Vol. 17, New Series of Plant Science Books, Chronica Botanica Co., Waltham, Mass.

APPENDICES

Appendix 1: Station data.

Appendix 2: Foraminiferal data.

(In pocket inside back cover).

APPENDIX I Sample station data

STATION NO.	SP 2	4	5	7	8	9	10	11	12	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	SU 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
DEPTH (METRES)	51½	33½	22	13½	27	18½	5½	17½	14½	11	6	39½	33½	28	14	14	10	8	5	4½	10	18	27	33	38	43	11	9	8	6	6	15	14	12	12	8	5	4½	5	5	6	6	6	6	6	6	50	4½	5	5	6	23	19	14½	11	8	5½	34½	28	22	17	10½	5
VOL. SEDIMENT (ml)	290	14	118	186	120	248	230	172	276	118	122	110	154	268	118	98	110	246	165	124	100	200	190	255	322	303	162	185	146	270	115	182	195	250	180	165	104	245	19	190	290	100	172	125	98	108	275	305	430	490	165	390	112	153	143	140	130	372	222	102	114	183	170
SURFACE AREA (cm^2)	317	108	236	276	240	302	288	269	312	235	242	228	262	308	238	224	228	300	265	242	225	282	277	304	327	320	284	275	256	308	235	273	279	302	273	266	227	300	127	377	322	224	270	245	224	234	310	322	359	375	265	348	232	260	251	250	247	343	288	223	233	271	268
% > 200 MESH	2	4	6	4	5	14	26	68	81	28	23	2	2	3	43	90	40	69	89	96	33	13	4	1	2	1	5	4	7	2	20	2	6	6	22	16	58	49	47	21	19	11	16	11	3	11	1	43	8	8	9	8	32	77	99	96	100	2	3	7	20	96	97
WT. FLOAT (mgr.)	426	-	108	302	40	508	44	443	1090	40	35	19	60	376	287	129	22	66	32	26	17	336	418	595	338	220	407	259	119	148	377	363	406	685	560	396	812	618	947	1070	224	329	1034	726	237	120	1307	816	2871	3419	464	1137	614	79	244	148	98	836	552	362	310	169	42
WT. 50 cm^2	64	-	43	55	16	84	8	83	175	9	7	5	12	61	61	66	5	13	6	5	4	60	75	98	52	34	77	47	35	24	164	67	73	113	102	74	179	103	184	142	348	66	191	180	58	28	221	213	334	456	122	163	132	22	49	28	19	121	96	81	67	31	10
SURFACE TEMP. °C	13	13½	13	-	13½	13½	13½	13½	13½	14	14	14	13½	14	14	14	14	14	14½	14	14	14½	14½	14	14	14	15	15	15	15½	15½	14	14	14	14	14	14	15			14½	14½		14½		14½		27		27	25½		26½		26½		26½		26½		26½		26	
BOTTOM TEMP. °C		13½	13½		14	14	14	14½			13½		15	15	15			15		15		16		15½	15		16		16		16½	15½		15½		14½		13½			14				13½		27		27	26		25½		26		25		25½		26		
SALINITY °/oo		38.8	38.8		38.8	37.3	38.1	38.9			38.7	39.7		39.7		39.1		39.3		38.4		39.2		38.9		38.8	39.1				38.9	38.8		37.2		39.4			38.5			37.8			38.3		38.2			38.4	38.4		38.8		37.5		38.5		38.0		37.9	

STATION NO.	SU 18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	S 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	19A	20	21	22	23	26	27	28	29	30	31	32
DEPTH (METRES)	14½	14	13½	11½	10	6	4	46	31½	20	14	10	7	5	8	12½	5	8	4½	8	9	11	12	13	9	8½	7	5	5½	5	5	34½	5	33½	20	12	11½	11½	10½	8	5	17½	16	14	10	3	3½	2½	3	3	3½	3½	6	8	1	1½	2	1½	1½	1	¾
VOL. SEDIMENT (ml.)	106	300	135	270	120	125	115	547	580	182	570	260	495	136	298	200	135	148	180	103	105	204	240	210	158	335	120	220	245	495	202	292	220	180	190	200	155	185	160	105	120	130	40	130	145	100	135	490	340	130	115	120	120	155	580	125	740	805	100	340	650
SURFACE AREA (cm^2)	230	320	247	309	240	245	232	388	395	273	393	311	376	247	319	280	246	257	270	227	230	281	297	284	259	332	240	288	299	377	280	317	288	274	275	280	258	272	260	230	238	247	165	244	252	225	250	375	333	247	232	235	235	258	395	240	430	440	222	335	410
% > 200 MESH	6	4	5	10	19	30	88	1	1	2	4	2	2	97	27	10	95	91	99	76	100	46	79	18	4	4	18	5	9	10	11	2	96	4	71	97	94	92	88	89	96	5	3	19	82	96	94	59	62	39	44	70	25	8	22	60	7	7	18	13	13
WT. FLOAT (mgr.)	441	1303	523	793	387	138	514	341	382	53	467	288	350	141	339	231	76	46	41	53	62	469	521	366	344	391	69	416	1627	1780	626	515	29	92	918	224	98	75	194	97	57	299	89	303	195	52	66	1894	2756	2121	624	236	61	1660	7065	4998	3290	3045	944	1801	2893
WT. 50 cm^2	106	207	106	128	93	48	111	44	48	13	60	46	47	29	53	41	15	13	8	14	12	84	88	65	66	59	26	72	195	236	120	81	5	23	167	50	19	14	30	25	12	75	34	62	38	15	13	209	413	71	350	88	23	321	894	1041	382	346	212	268	352
SURFACE TEMP. °C		26½			26	27		26		27		26			26	26		26		26½				26		26		26	27		26½				21			22			21½	22			22			25				24½		23	24		24½			24		
BOTTOM TEMP. °C		26			25½	26½		25		26		26			25	26		26		26				25½		26		26			26				20			22			21	21			21½			24½				24		23							
SALINITY °/oo		38.1				38.6		38.6		38.5		38.7				38.3		38.0				37.9		38.8		38.9		38.4			38.1				38.5			38.2			38.8	38.0			37.7			36.5				38.1		37.6	2.6		.8		.8	.9	.7

APPENDIX 3

ES SAMPLES

Many foraminiferid samples, both from Recent and Tertiary sediments all over Europe, were collected by, or on behalf of the author for comparison with the Ebro delta fauna. Several workers kindly exchanged material. The purpose of the collection was, as has been pointed out in the text, to note the occurrence of species occurring in the Ebro delta fauna in other areas, with a view to determining their distribution in the European area and to help derive their origins. Other samples in the Protozoa section of the British Museum of Natural History were also examined for this purpose.

Considerable care has been taken with comparisons. Foraminiferids from a single beach sand sample, for example, cannot be taken as indicative of the whole fauna living offshore in that area. Similarly, a deep water sample could not be directly compared with the relatively shallow water samples around the Ebro delta.

Details of the location, age, etc. of the samples are given below:

ES/1 Locmariaguer, Brittany; intertidal mud.

2 Trinité - sur - Mer, Brittany; beach sand.

3 San Remo, Italy; beach sand.

4 Lido de Sottomarina, Italy (Adriatic); beach sand.

5 Coast of Brittany; beach sand.

ES/8 - 31 Stagnone, Sicily; shallow water, lagoonal sediments, living and dead foraminiferids.

32 Llafranch, Costa Brava, northeastern Spain; beach sand.

33 Alassio, Italy (Adriatic); beach sand.

34 - 37 Chillesford Beds, Chillesford, Suffolk; Lower Pleistocene (Icenian), clays and sands.

38 Red Crag (Butlevian), Butley, Suffolk; Pliocene sands.

39 Red Crag (Newbournian), Newbourne, Suffolk; Pliocene shelly sand.

40 - 41 Coralline Crag, Gedgrave, Suffolk; Pliocene sands.

42 Hammumet, Tunisia; beach sand.

43 - 55 Rhône delta; clays and sand from 5 - 98 m. depth.

56 - 64 Majorca, southeast of Mallorca, depths 63 - 452 m.

65 Canary Isles; shallow water sand.

66 Dogs Bay, Connemara; dune sand.

67 Scheveninger, Holland; beach sand.

68 Rimini, Italy (Adriatic); beach sand.

69 Gargaresh Lagoon, Tripoli; shell sand, 2 m. depth.

70 Piraeus Harbour, Athens; coarse sand, 4 m. depth.

71 Bay of Elensis, Greece; shell sand 18 m. depth.

72 Cape St. Martin, Monaco; shell sand, 50 m. depth.

73 Ragusa, Yugoslavia (Adriatic); sand, 22 m. depth.

74 Gulf of Ajaccio, Corsica; beach sand.

75 Island of Delos, Grecian Archipelago; shell sand 23 m. depth.

76 Tripoli; beach sand.

77 Taquira, Libya; shallow water sand, 2 m. depth.

78 Sirte, Libya; beach sand.

80 Trawling grounds south of Aberystwyth; mud, 20 m. depth, living and dead foraminiferids.

81 Rozel Bay, Jersey, Channel Islands; beach sand.

82 San Regolo, Italy; Pliocene shell sand.

83 Lower Miocene (Aquitanian), Rhône Valley.

84 Upper Oligocene, Astrup bn Osnabrück, Austria.

85 Lower Miocene (Burdigalian), Bayern.

90 Middle Miocene, (Helvetian), Marnière de Havrant, Saubrigues, France.

91 Gîte d'Apigné, nr. Rennes, France; Redonian (Pliocene?).

92 Lower Miocene (Aquitainian), Marnière de Escornebéou, France.

93 Skagerak, sand 250 m. depth.

94 Avonmouth; sandy gravel (?Pleistocene).

PLATES

NOTE

Photographs presented in the following plates were taken by means of a Scanning Electron microscope manufactured by Cambridge Instruments Ltd. This instrument is a relatively recent innovation and has opened a new field in the examination of microfossils (it has numerous other uses as well). Its great powers of magnification, while still preserving a considerable depth of field, are ideally suited to the study of foraminiferids.

All the following photographs were taken on very low magnifications but the scope of the microscope is much greater, allowing examination of test structures, surface textures etc. Scanning Electron Microscope study is as yet in its infancy but already there have been several published studies incorporating scanning electron photomicrographs; for example, Honjo and Bergren (1967), Bartlett (1968) and Boltovskoy (1969).

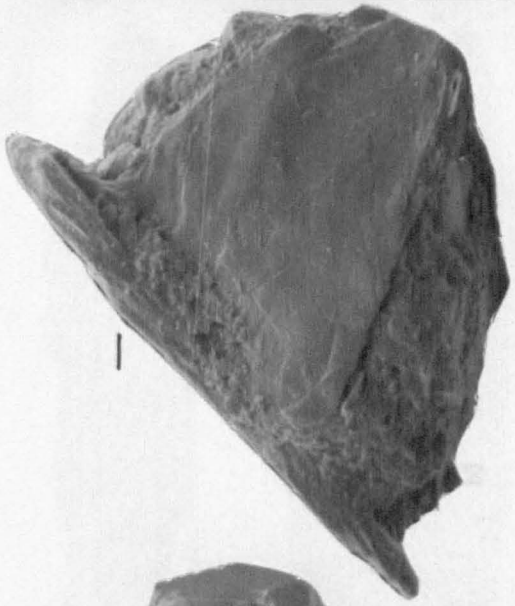
With regard to the following photographs, a number of minor practical difficulties arose during the photography. The performance of the Scanning Electron Microscope varied from day to day, depending among other things upon the age of the main filiament, and this resulted in good or poorer photographs. Because of time limitations and the large number of foraminiferid species to be photographed, a relatively poor photograph could not always be repeated. Therefore the quality of the individual photographs in the plates varies but they are invariably superior to those that could have been produced by other photographic techniques.

Prior to scanning, specimens are coated thinly with a gold / palladium alloy and this poses a number of small problems. Sometimes, if the coating is not complete, 'scan lines' may appear

across the photograph (e.g. plate 15, figure 1a), while in other cases the coating may crack and flake off slightly (e.g. plate 12, figure 2b). Species with smooth surfaces and no surface relief on their tests do not photograph well because the coating obscures sutures and other features that are normally visible (e.g. plate 12, figure 2b). On the other hand, species with good surface relief, such as the Textulariina, photograph exceptionally well. Occasionally, slightly broken specimens were inadvertantly mounted for scanning. It was usually not possible to make out these small breaks under the conventional microscope, whereas the high magnifications of the Scanning Electron Microscope makes them all too apparent (e.g. plate 8, figure 2).

Despite these few drawbacks, it is thought that the quality and clarity of the photographs far exceeds that in those of most previous foraminiferid studies, and the author wishes to express his appreciation of the several hours of work spent by Mr. C.A. Wright in operating the microscope.

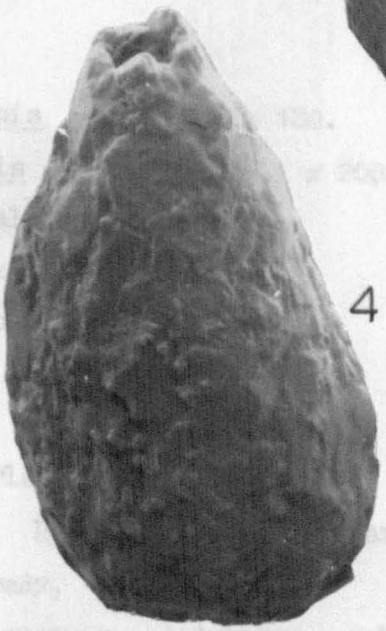
PLATE 1



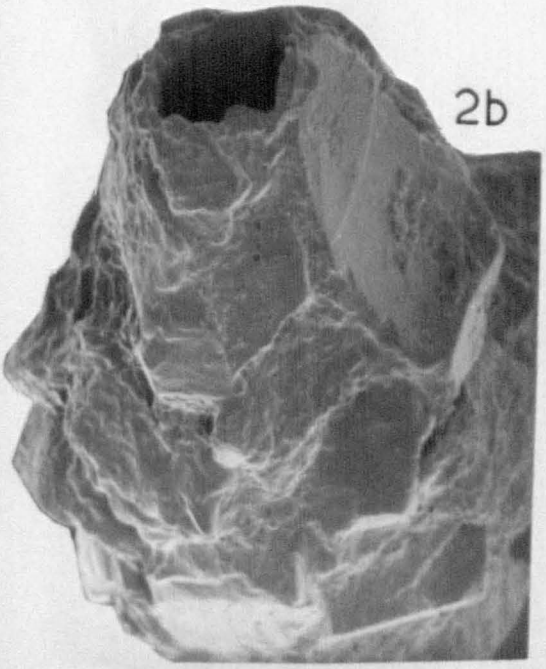
1

3

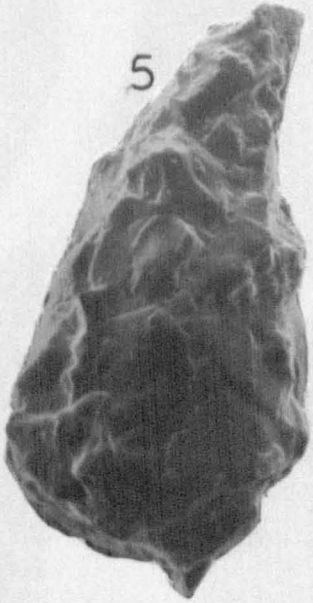
2a



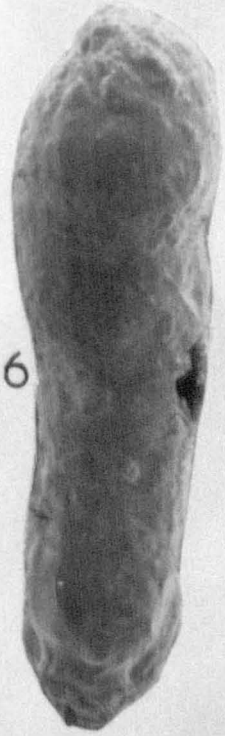
4



2b



5



6

PLATE 2

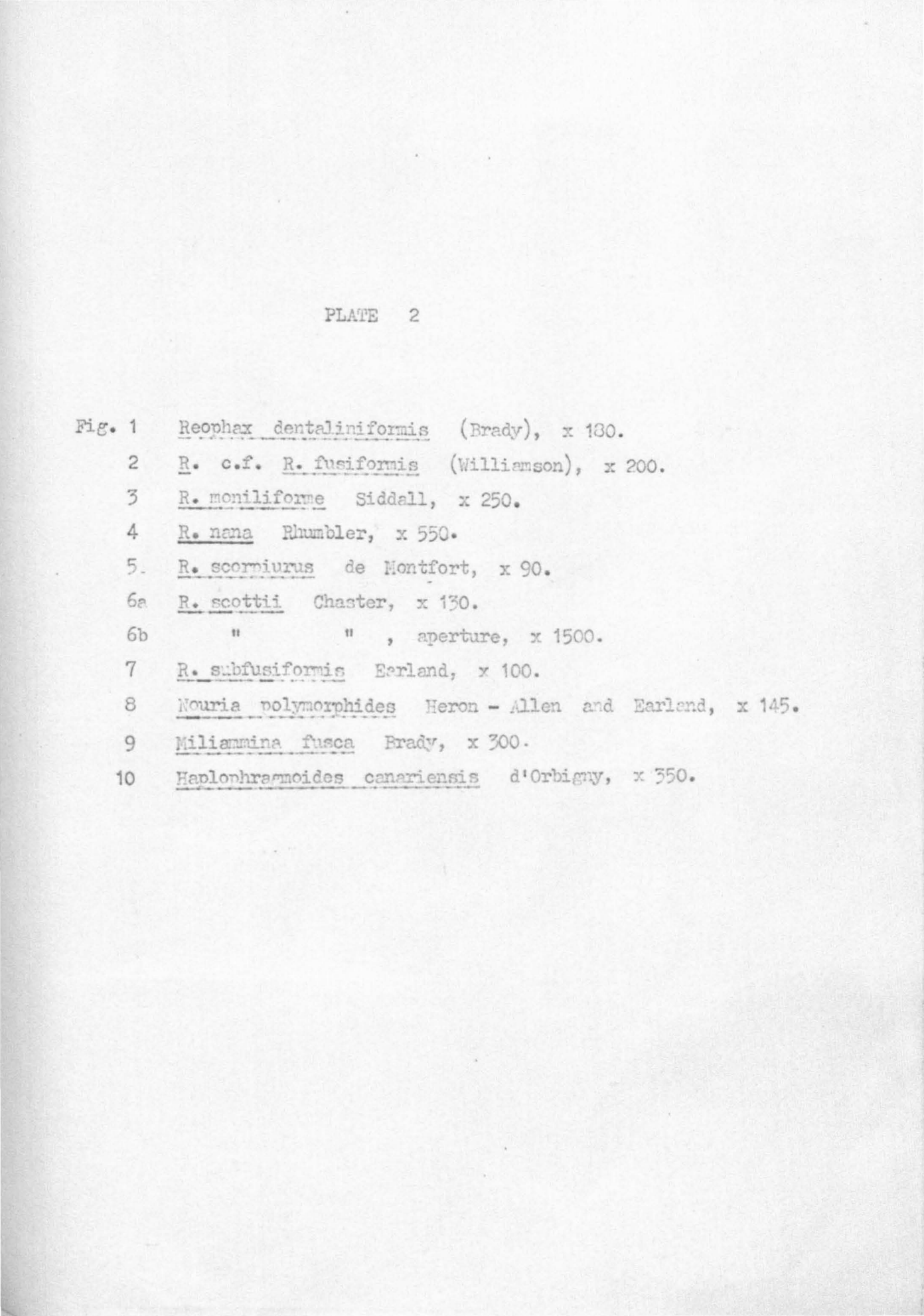


Fig. 1 Reophax dentaliniformis (Brady), x 180.

2 R. c.f. R. fusiformis (Williamson), x 200.

3 R. moniliforme Siddall, x 250.

4 R. nana Rhumbler, x 550.

5. R. scorpiurus de Montfort, x 90.

6a R. scottii Chaster, x 130.

6b " " , aperture, x 1500.

7 R. subfusiformis Earland, x 100.

8 Nouria polymorphides Heron - Allen and Earland, x 145.

9 Miliammina fusca Brady, x 300.

10 Haplophragmoides canariensis d'Orbigny, x 350.

PLATE 2

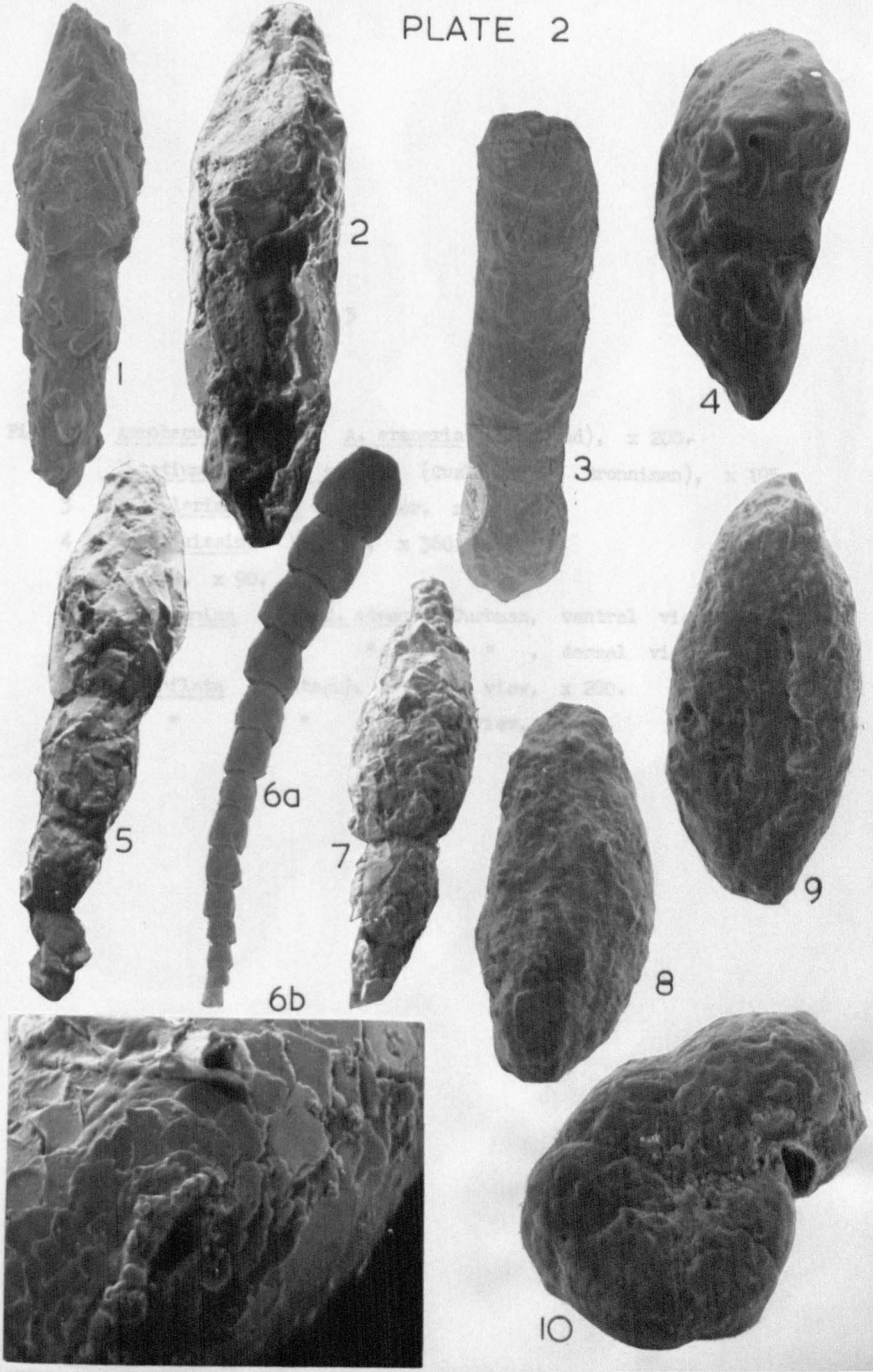


PLATE 3

Fig. 1 *Ammobaculites* c.f. *A. arenaria* (Natland), x 200.

2 *Ammotium* c.f. *A. salsum* (Cushman and Bronniman), x 195.

3 *Textularia calva* Lalicker, x 140.

4 *T. tenuissima* Earland, x 360.

5 *T.* sp., x 90.

6a *Trochammina* c.f. *T. advena* Cushman, ventral view, x 240.

6b " " " , dorsal view, x 240.

7a *T. inflata* (Montagu), ventral view, x 280.

7b " " , dorsal view, x 280.

PLATE 3

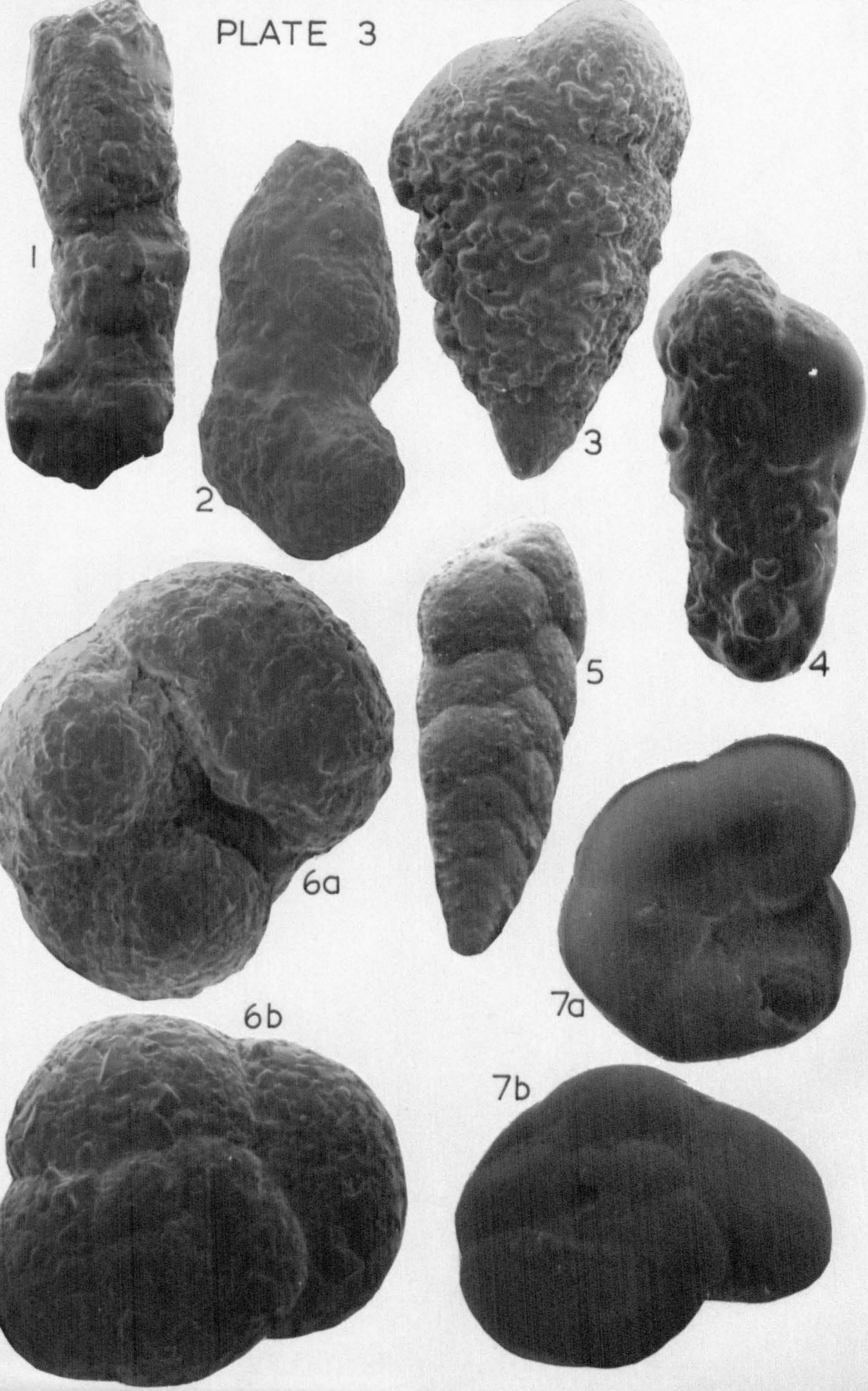


PLATE 4

Fig. 1a *Trochammina lobata* Cushman, ventral view, x 235.

1b " " " , dorsal view, x 250.

2a *T.* sp., dorsal view, x 360.

2b " , ventral view, x 310.

3 *Ammosphaeroidina sphaeroidiniformis* (Brady), x 300.

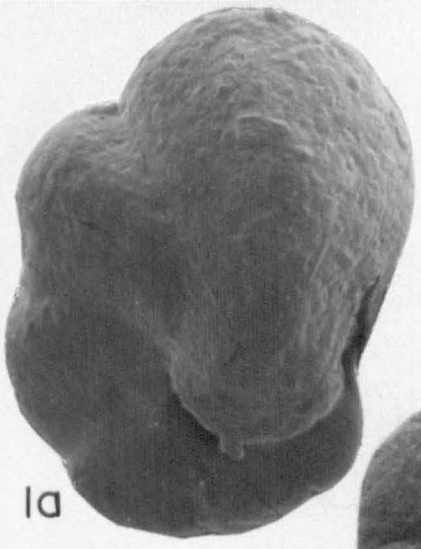
4 *Jadammina macrescens* (Brady), x 300.

5 *Eggerella scabra* (Williamson), x 220.

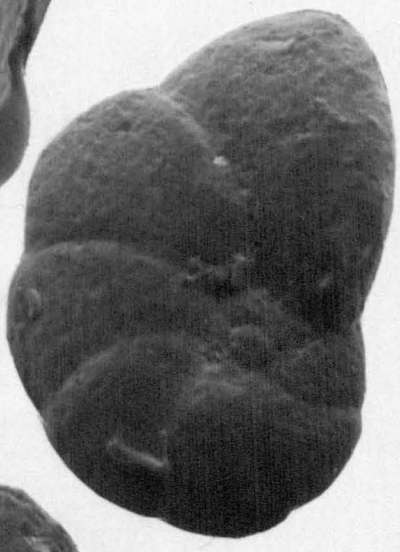
6 *E. advena* (Cushman), x 480.

7 *Clavulina obscura* Chaster, x 355.

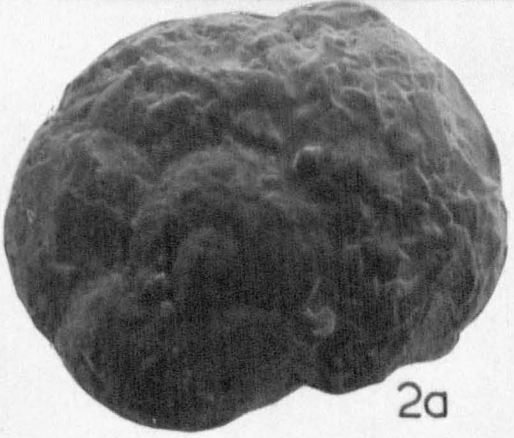
PLATE 4



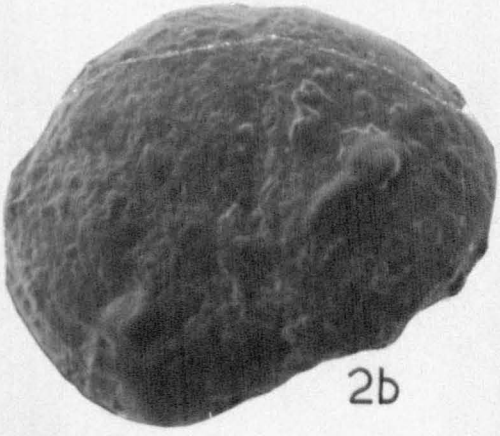
1a



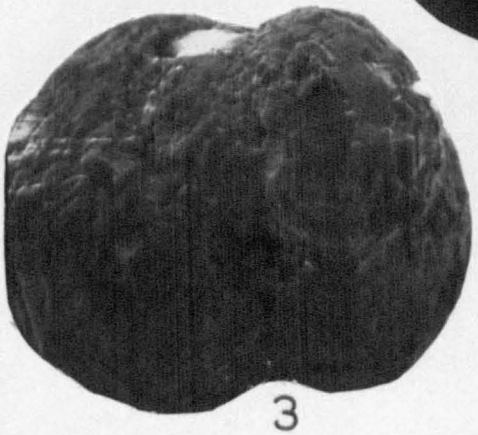
1b



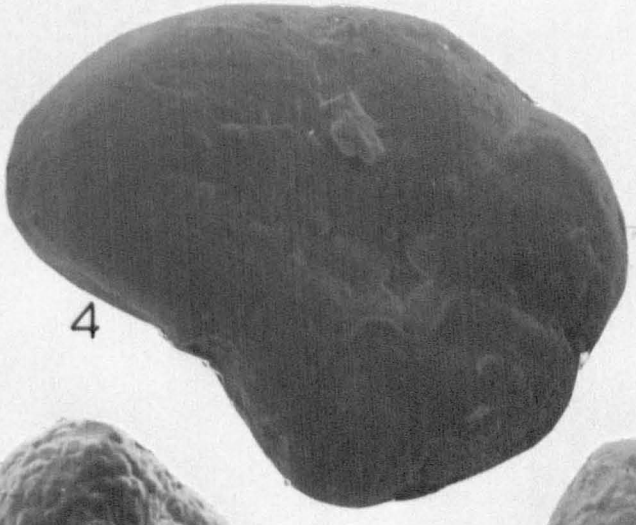
2a



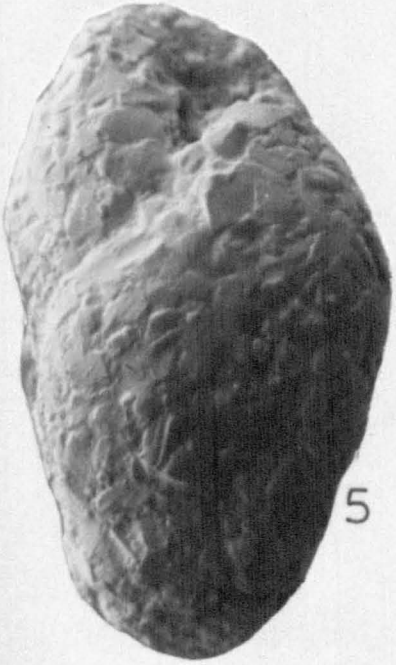
2b



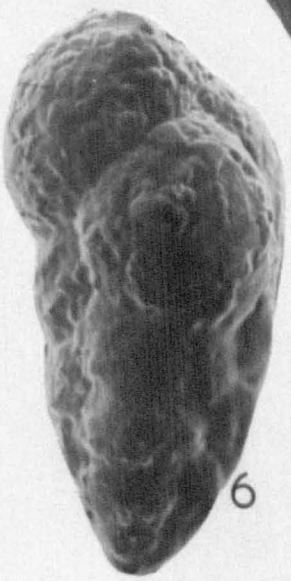
3



4



5



6

7

PLATE 5

Fig. 1 Cyclogyra incerta d'Orbigny, x 210.

2a Vertebralina striata d'Orbigny, ventral view, x 115.

2b " " " , dorsal view, x 100.

3 Quinqueloculina depressa d'Orbigny, x 190.

4 Q. laevigata (d'Orbigny), x 265.

5a Q. longirostra d'Orbigny, x 86.

5b " " , opposite view, x 82.

6 Q. rugosa d'Orbigny, x 190.

PLATE 5

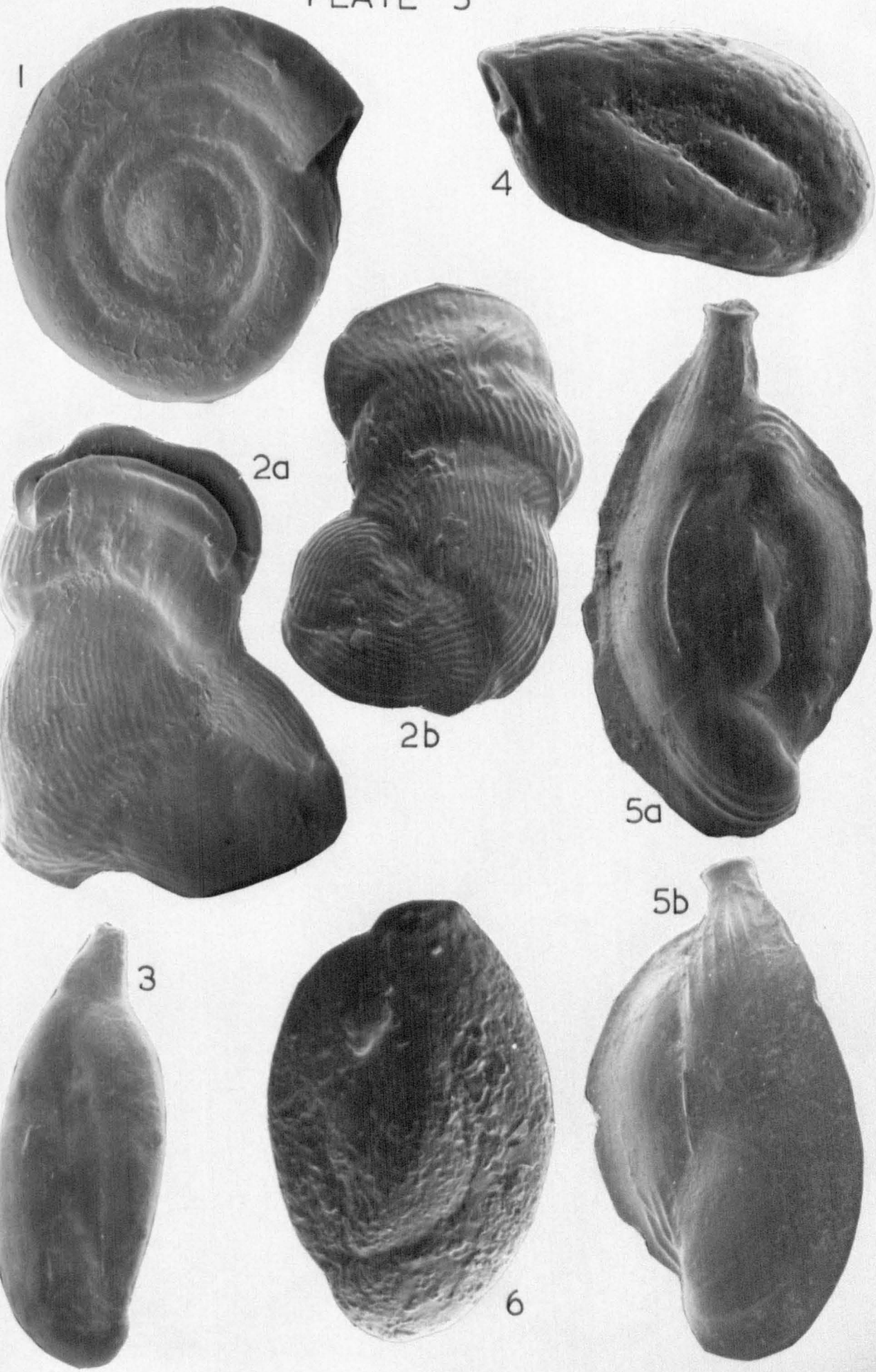


PLATE 6

Fig. 1 Quinqueloculina schlumbergeri (Weisner), x 355.

2 Q. seminulum (Linné), x 120.

3a Q. sp., x 150.

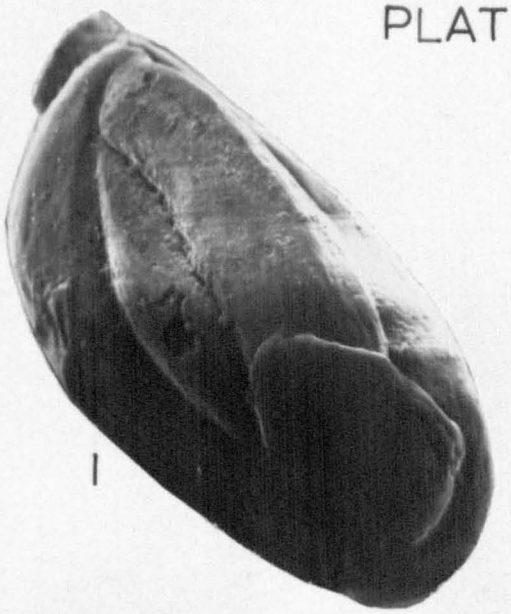
3b " , opposite view, x 135.

4 Pyrgo inornata (d'Orbigny), x 180.

5a Massilina secans (d'Orbigny), x 40.

5b " " " , opposite view, x 40.

PLATE 6



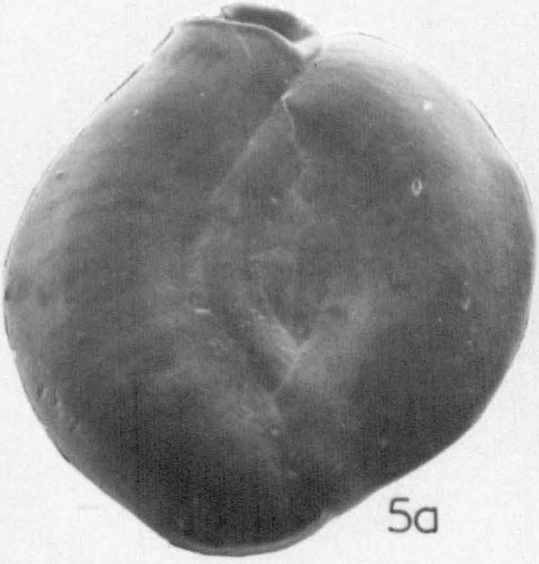
1

2

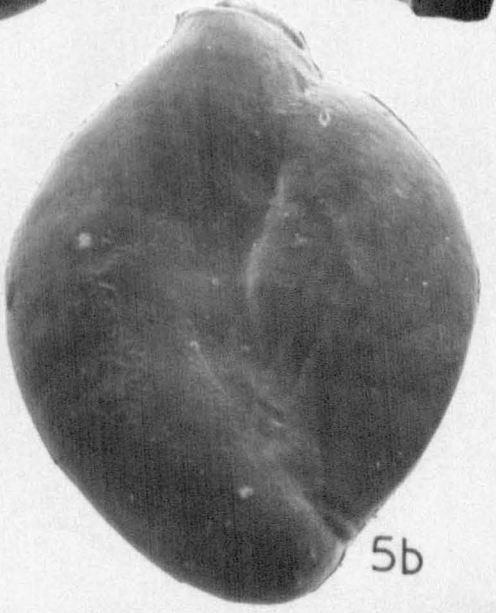
3a

3b

4



5a



5b

PLATE 7

Fig. 1a Triloculina dubia d'Orbigny, x 100.

1b " " " , opposite view, x 100.

2a T. marioni Schlumberger, x 140.

2b " " , opposite view, x 130.

3a T. rotunda d'Orbigny, x 100.

3b " " , aperture, x 280.

3c " " , opposite view to 3a, x 100.

4a T. sp., x 375.

4b " , opposite view, x 350.

PLATE 7

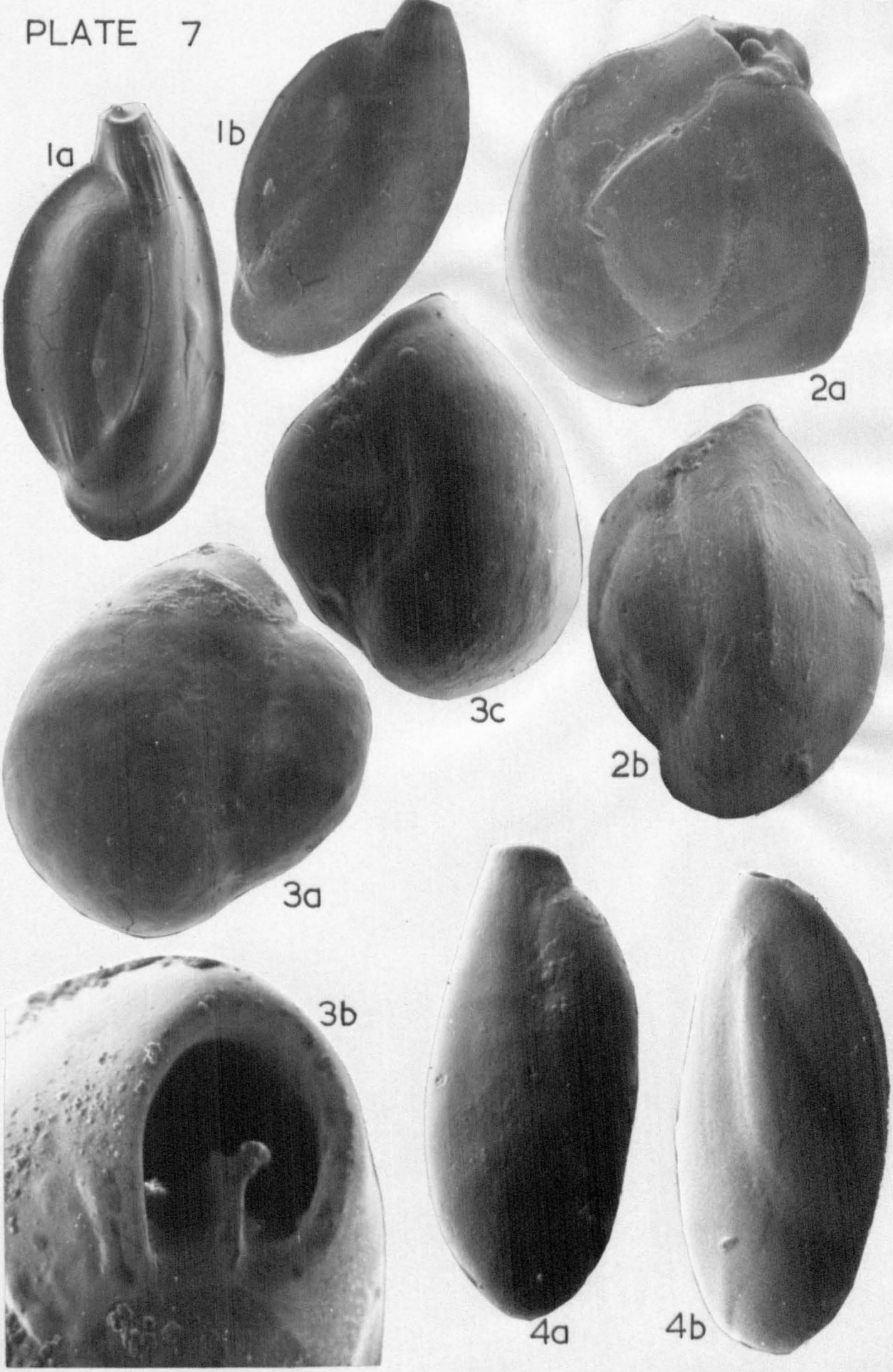


PLATE 8

Fig. 1 Amphicoryna scalaris (Batsch), x 200.

2 Lagena clavata (d'Orbigny), x 140.

3 L. c.f. L. semistriata Williamson, x 195.

4 L. substriata Williamson, x 240.

5 L. sulcata Walker and Jacob, x 285.

6 L. tenuis (Bornemann), x 235.

7 L. vulgaris Williamson, x 255.

8 Fissurina lucida Williamson, x 405.

9 F. sp., x 335.

10a Buliminella elegantissima (d'Orbigny), x 370.

10b " " " , opposite view, x 350.

11 Bolivina pseudoplicata Heron - Allen and Earland, x 210.

PLATE 8

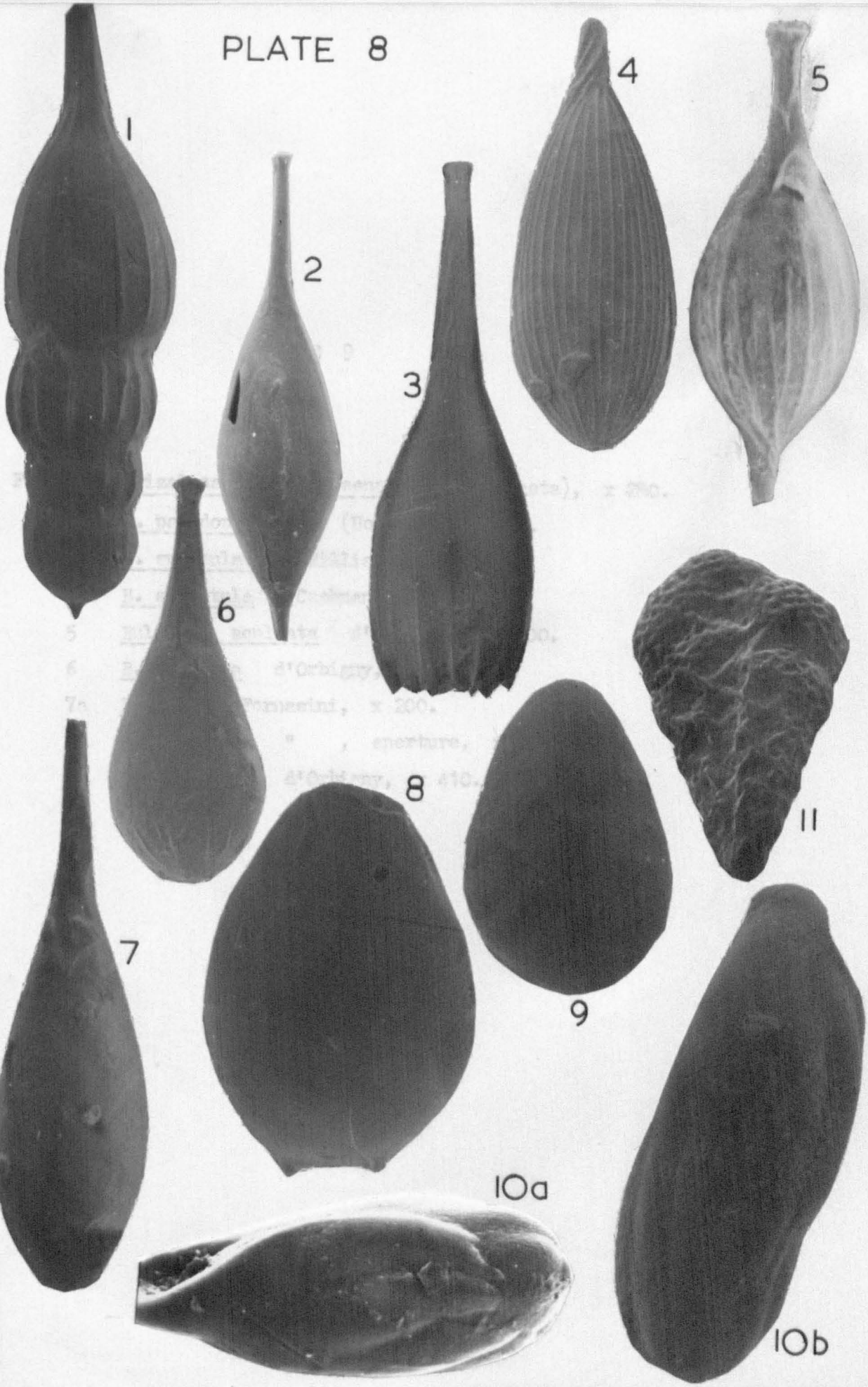


PLATE 9

Fig. 1 Brizalina c.f. B. aenariensis (Costa), x 280.

2 B. pseudopunctata (Hoglund), x 245.

3 B. spathulata (Williamson), x 205.

4 B. striatula (Cushman), x 200.

5 Bulimina aculeata d'Orbigny, x 300.

6 B. elongata d'Orbigny, x 200.

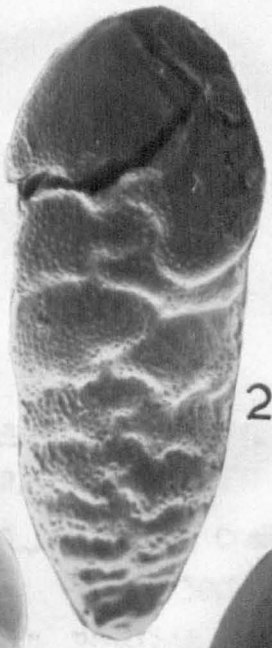
7a B. gibba Fornasini, x 200.

7b " " , aperture, x 1500.

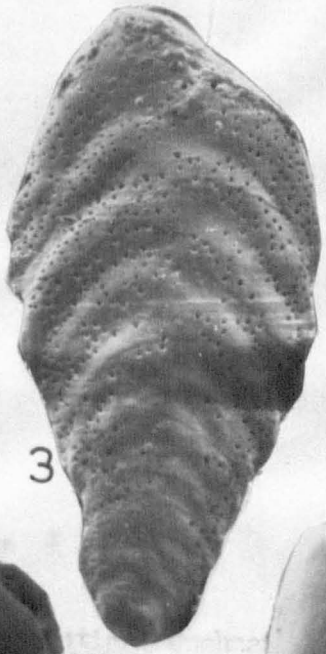
8 B. marginata d'Orbigny, x 410.

PLATE 9

1

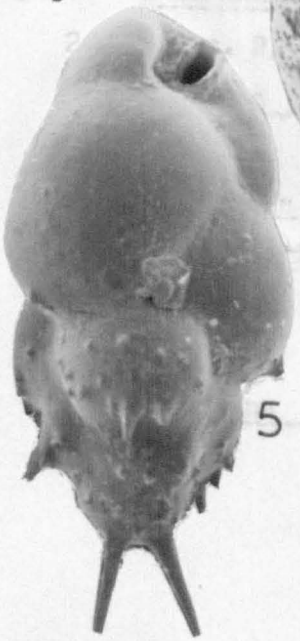


2



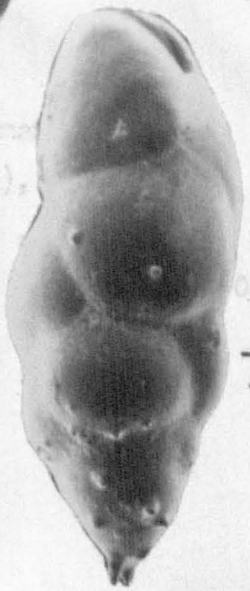
3

4

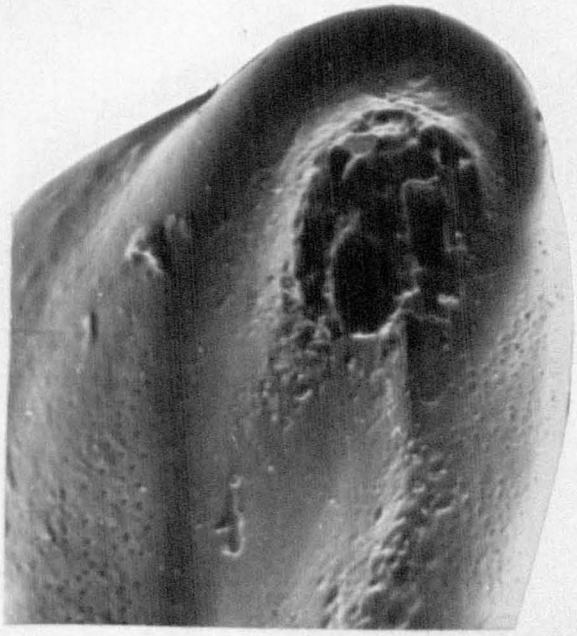


5

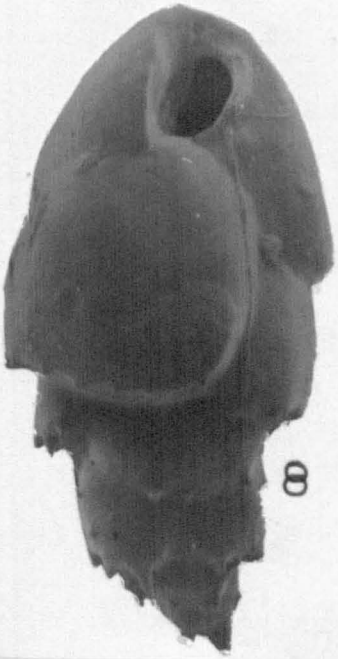
6



7a



7b



8

PLATE 10

Fig. 1 Bulimina sp. 1, x 255.

2 B. sp. 2, x 180.

3 Reusella aculeata Cushman, x 250.

4 Uvigerina sp., x 300.

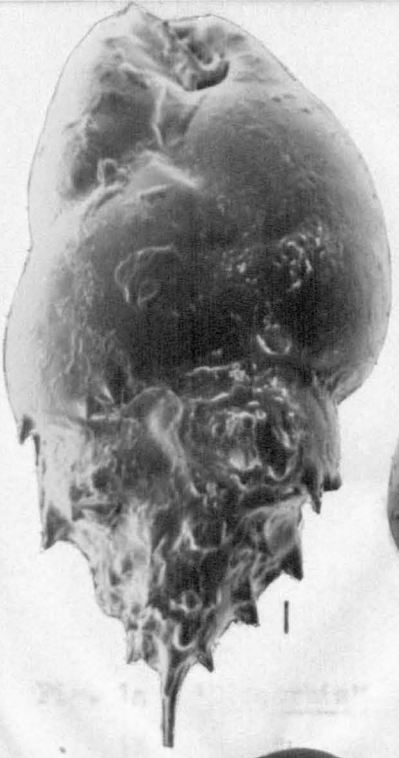
5 Hopkinsina pacifica var. atlantica Cushman, x 500.

6a Rectuvigerina c.f. R. compressa (Cushman), x 235.

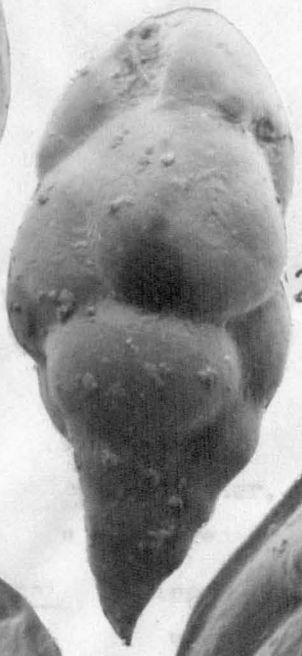
6b " " " , detail of spines, x 4750.

7 Triforina angulosa (Williamson), x 345.

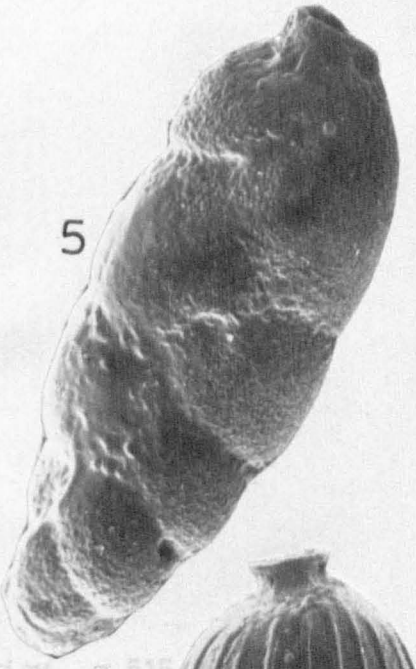
PLATE 10



1



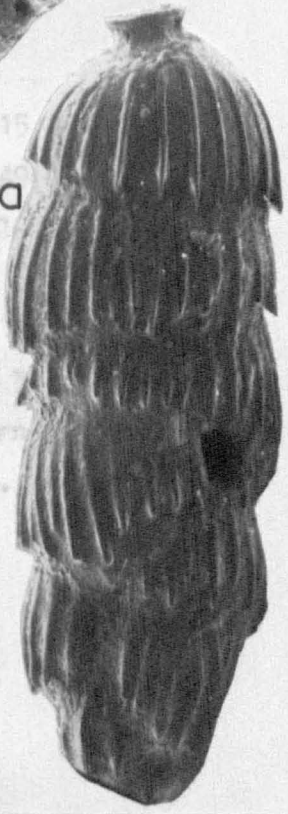
2



5

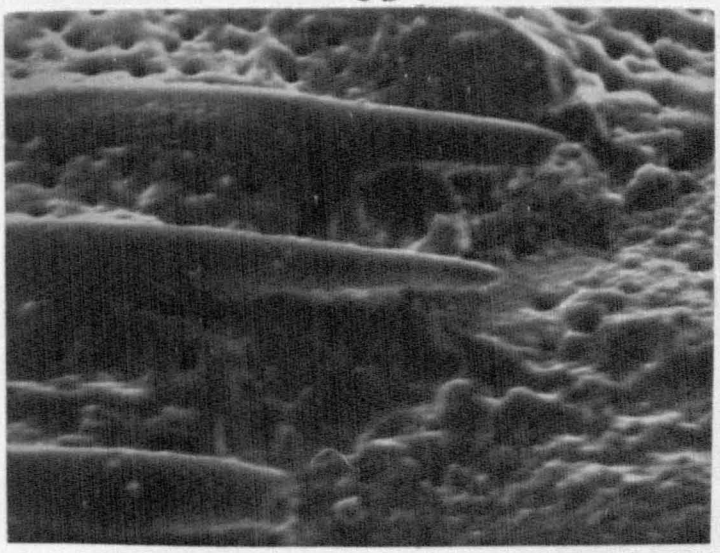
3

7



6a

6b



4

PLATE 11

Fig. 1a 'Discorbis' bulbosa Parker, dorsal view, x 515.

1b " " " , Ventral view, x 490.

2a Buccella hannai (Phleger and Parker), ventral view, x 400.

2b " " " " , dorsal view, x 370.

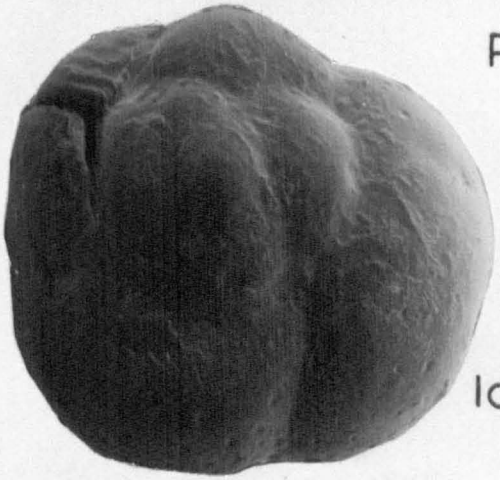
3a Epistominella vitrea Parker, ventral view, x 615.

3b " " " , dorsal view, x 370.

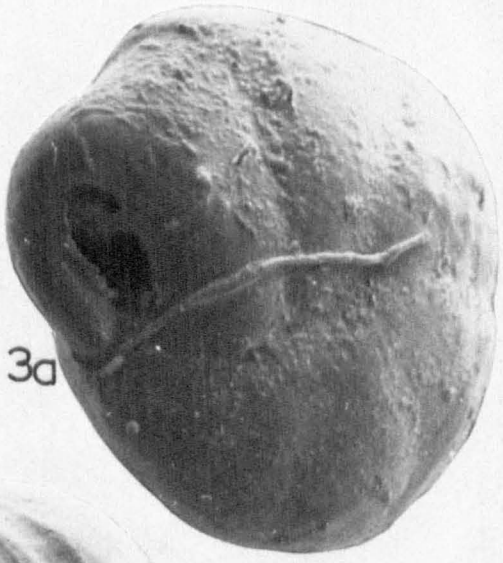
4a Gavelinopsis praegeri (Heron - Allen and Earland), dorsal view, x 260.

4b " " " " , ventral view, x 280.

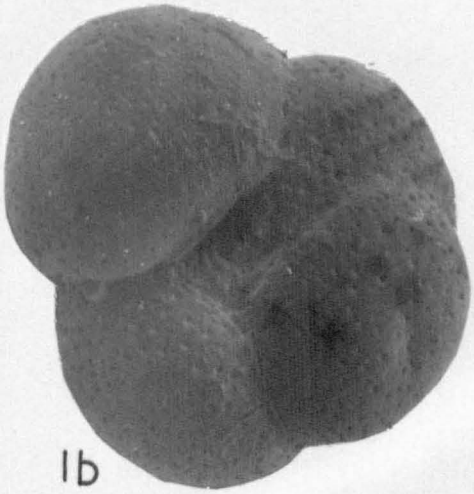
PLATE 11



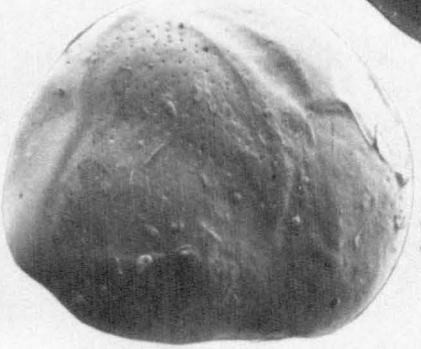
1a



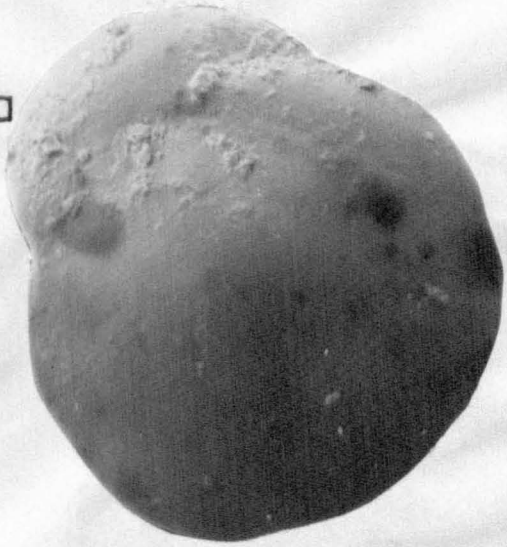
3a



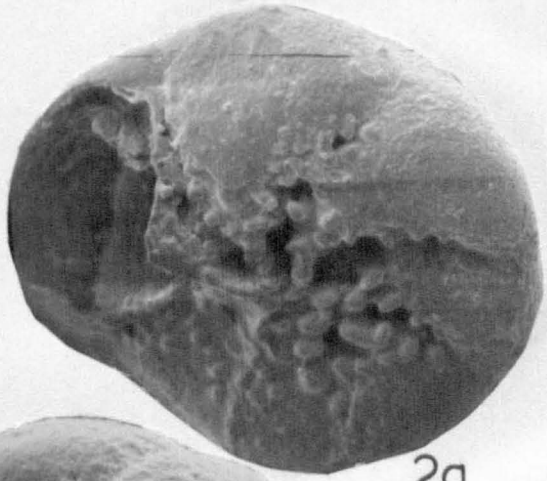
1b



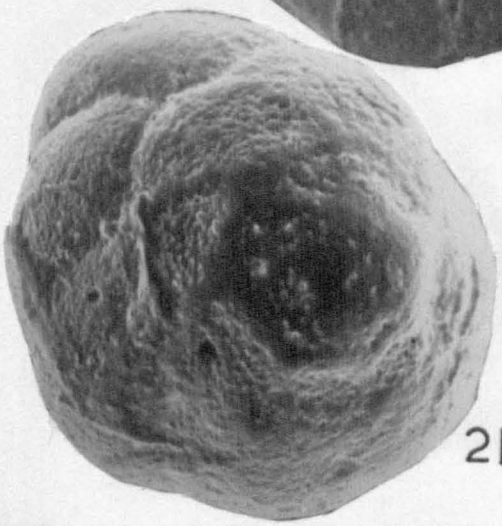
3b



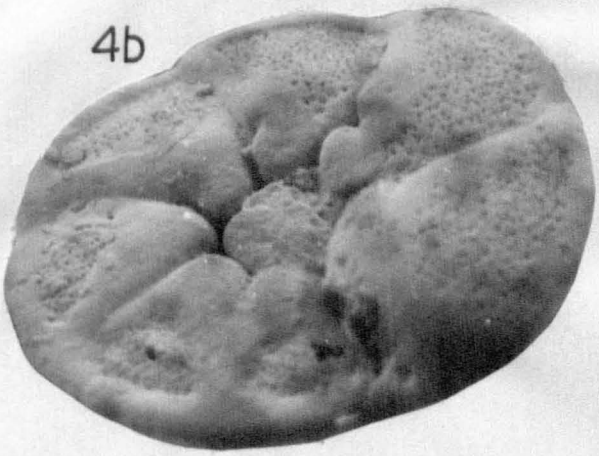
4a



2a



2b



4b

PLATE 12

Fig. 1a Rosalina concinna (Brady), dorsal view, x 260.

1b " " " , ventral view, x 240.

2a R. globularis d'Orbigny, ventral view, x 200.

2b " " , dorsal view, x 200.

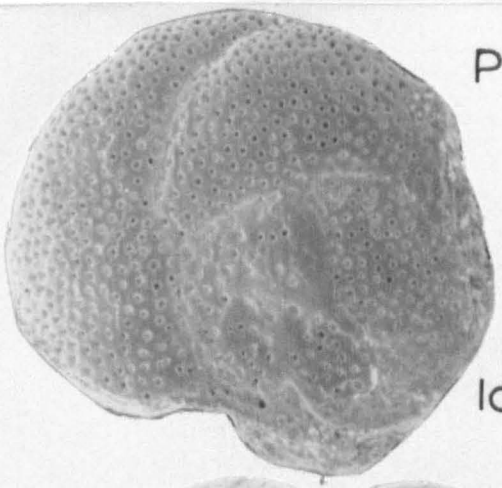
3a R. cf. R. mediterranensis d'Orbigny, ventral view, x 350.

3b " " , dorsal view, x 340.

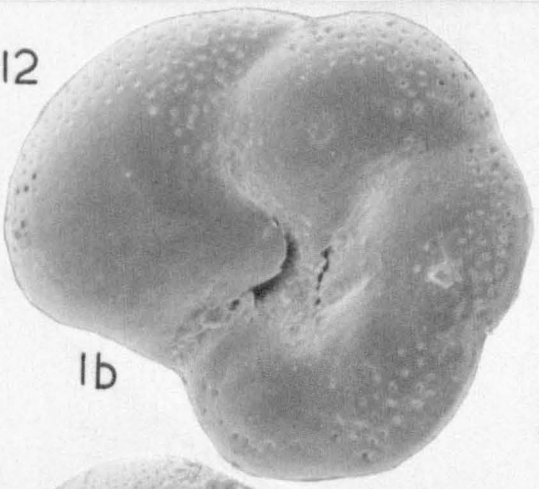
4a R. c.f. R. valvulata d'Orbigny, dorsal view, x 320.

4b " " , ventral view, x 300.

PLATE 12

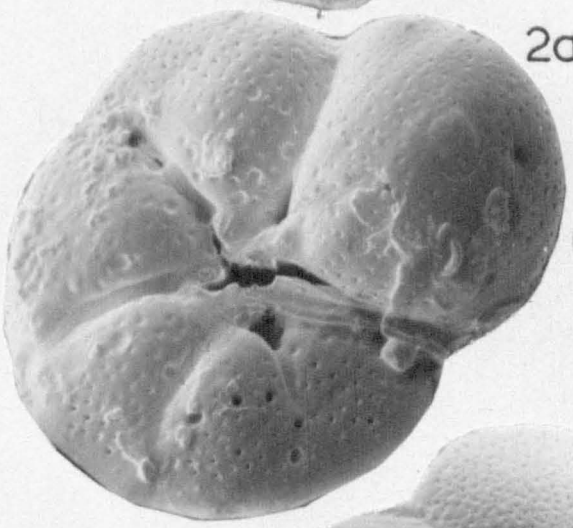


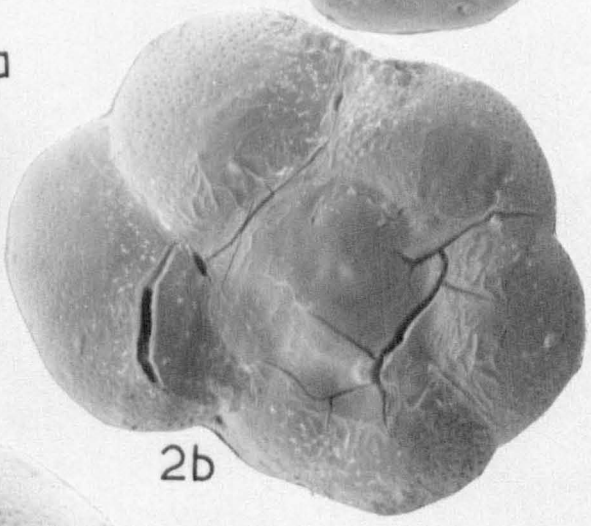
1a



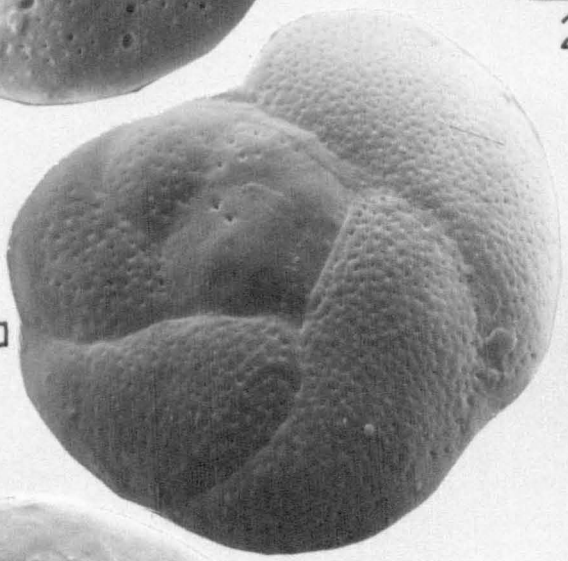
1b

2a



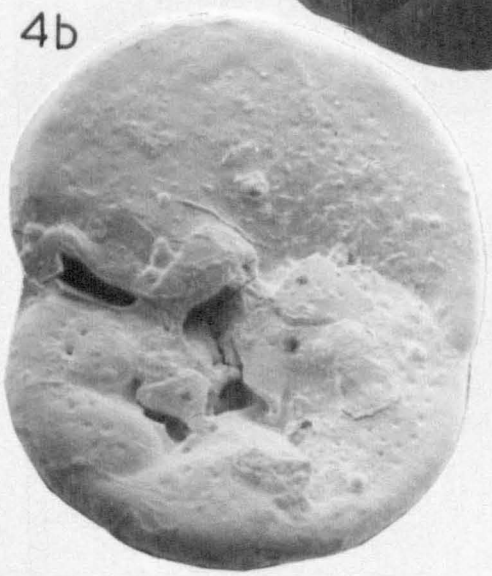


2b



4a

4b



3a

3b

PLATE 13

Fig. 1a *Valvulineria complanata* (d'Orbigny), dorsal view, x 220.

1b " " " , ventral view, x 240.

2a *Asterigerinata* sp., ventro - lateral view, x 460.

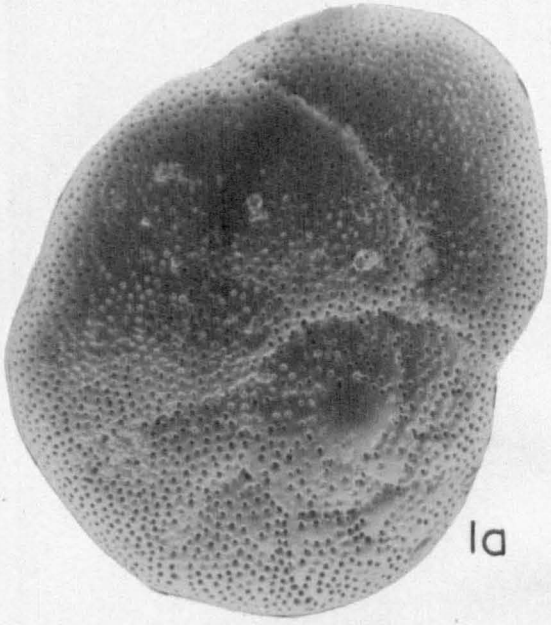
2b " , ventral view, x 680.

2c " , dorsal view, x 545.

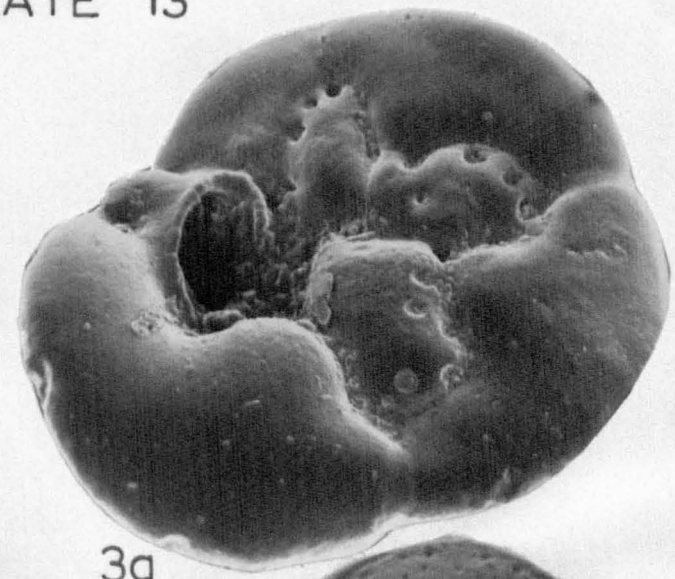
3a *A. mamilla* (Williamson), ventral view, x 280.

3b " " , dorsal view, x 215.

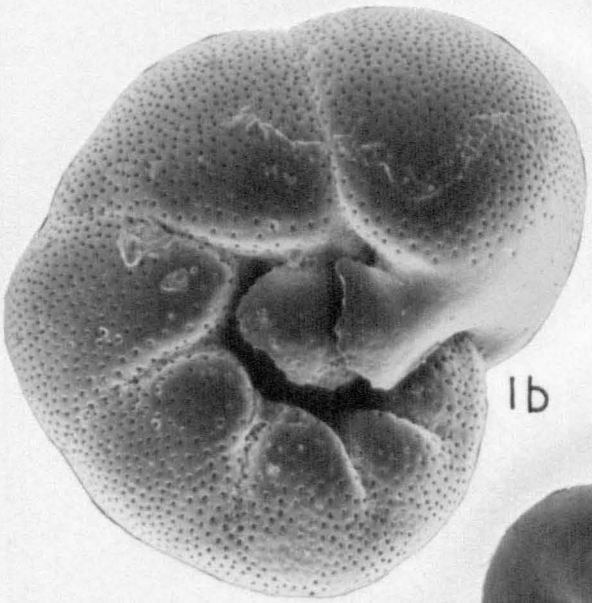
PLATE 13



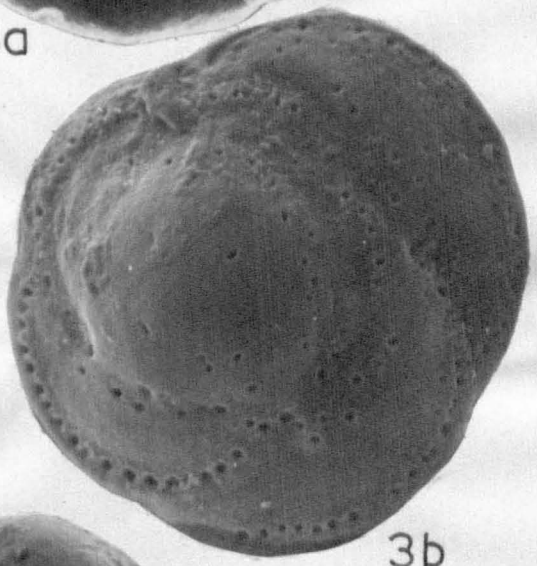
1a



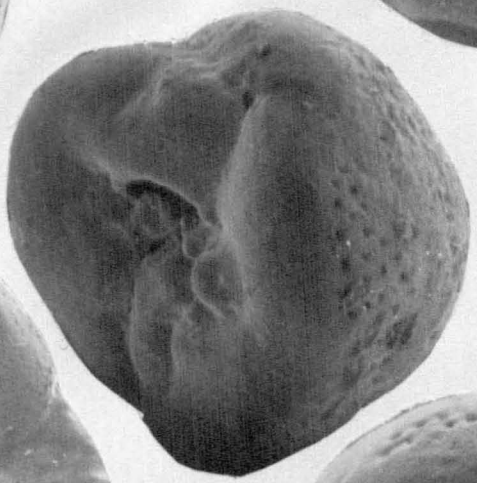
3a



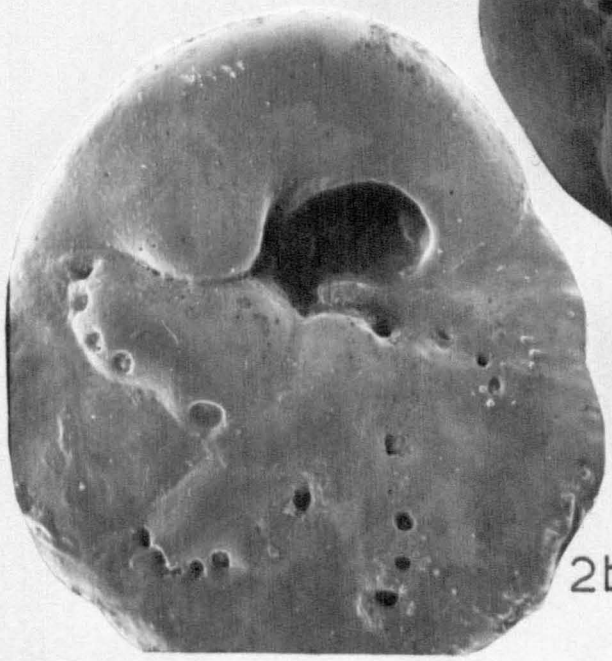
1b



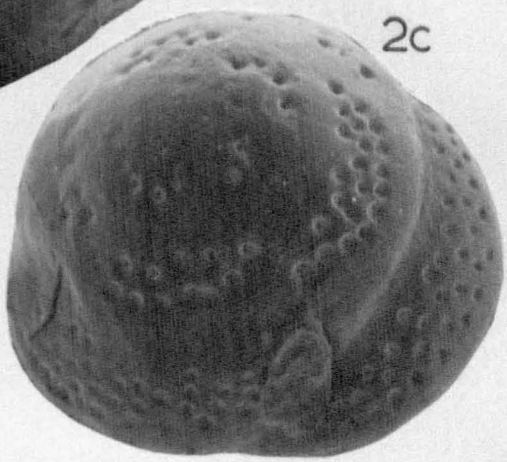
3b



2a



2b



2c

PLATE 14

Fig. 1a *Patellina corrugata* Williamson, ventral view, x 250.

1b " " " , dorsal view, x 180.

2a *'Rotalia' perlucida* Heron - Allen and Earland, ventral view, x 220.

2b " " " " , dorsal view, x 220.

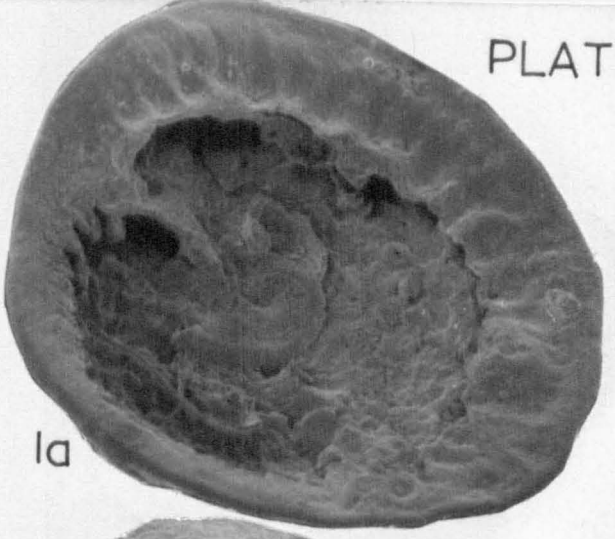
3a *Ammonia beccarii* (Linné) typica, ventral view, x 50.

3b " " " " , dorsal view, x 60.

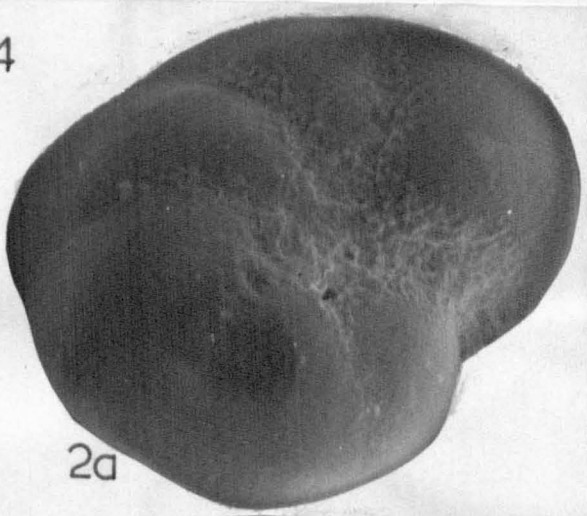
3c " " " var. *batavus* (Hofker), ventral view, x 185.

3d " " " " " , dorsal view, x 245.

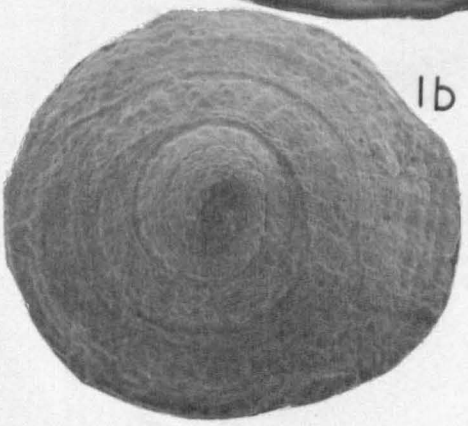
PLATE 14



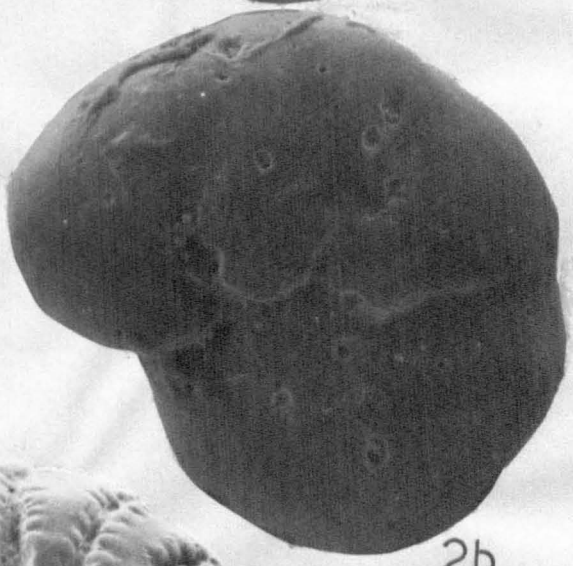
1a



2a

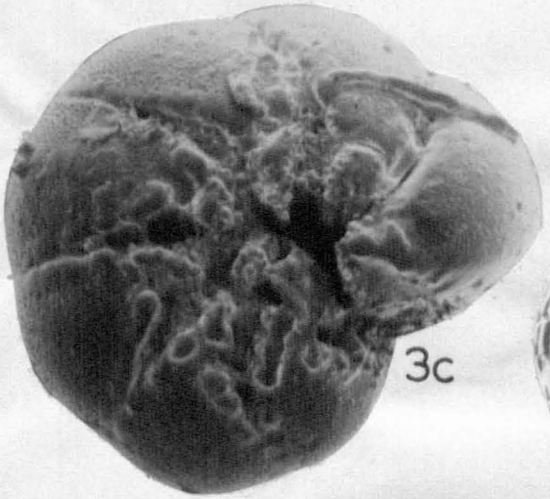


1b

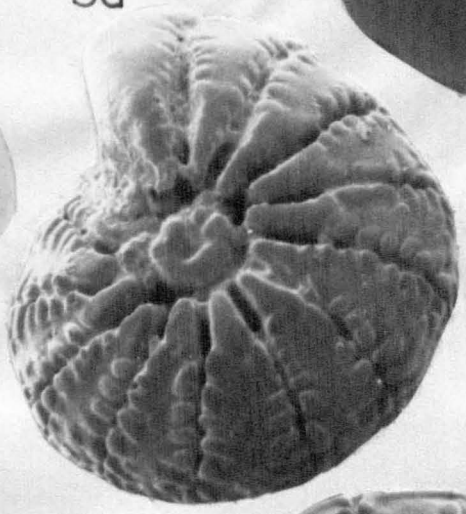


2b

3a

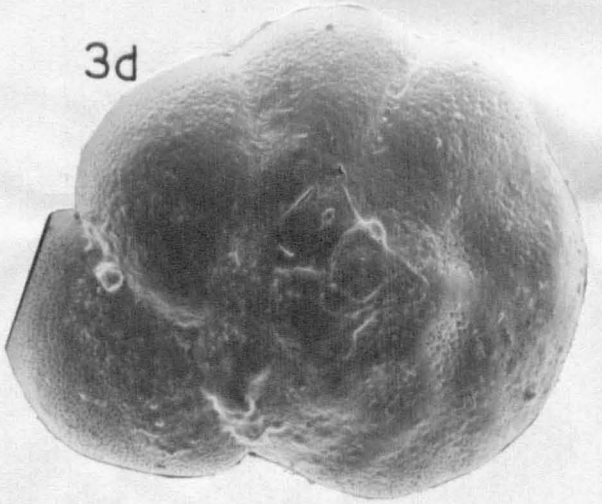


3c



3b

3d



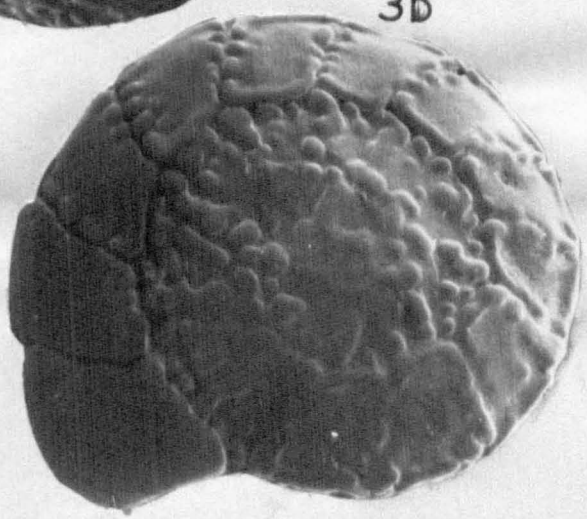


PLATE 15

Fig. 1a *Ammonia beccarii* (Linné) var. 3, x 210.

1b " " " var. 1, x 175.

1c " " " var. 2, x 500.

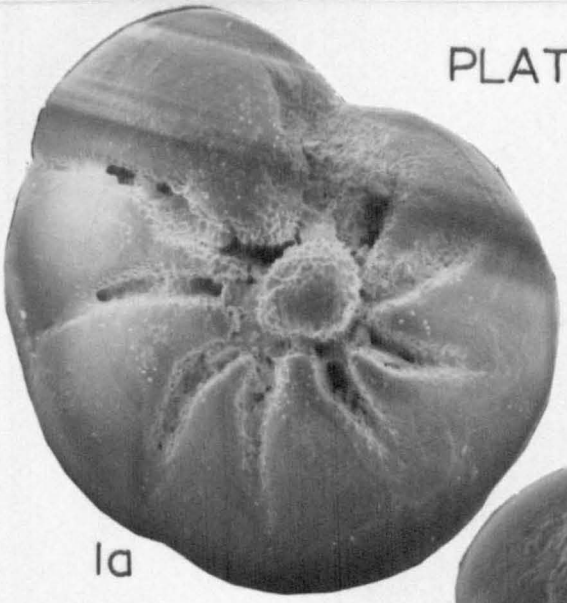
2 *Elphidium advenum* (Cushman), x 380.

3a *E. crispum* (Linné), details of retral processes, x 315.

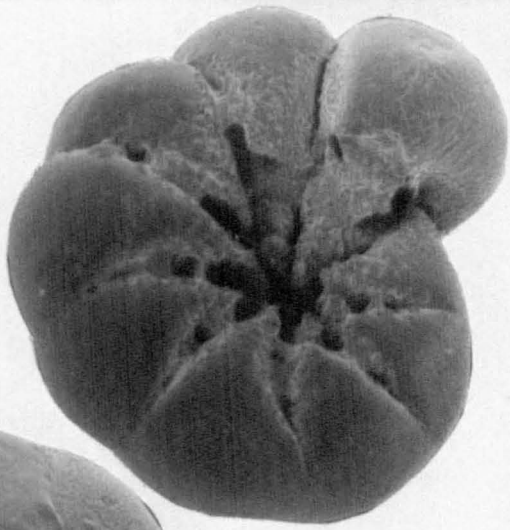
3b " " , x 88.

4 *E. excavatum* (Terquem), x 250.

PLATE 15

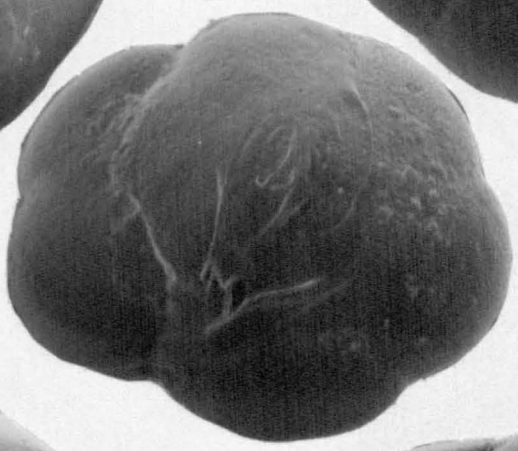


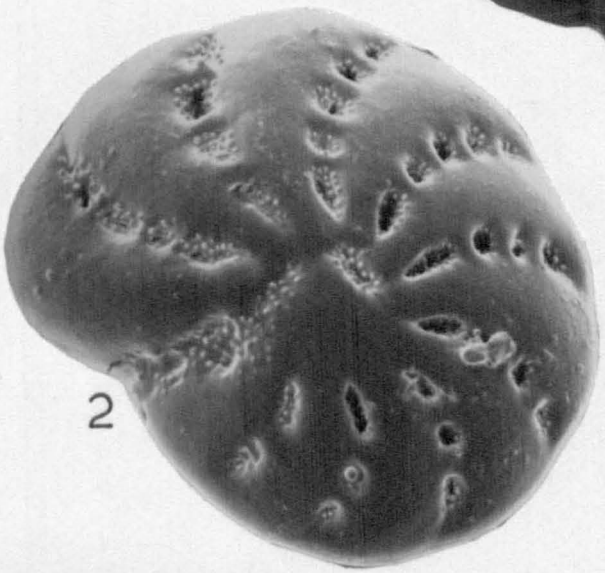
1a



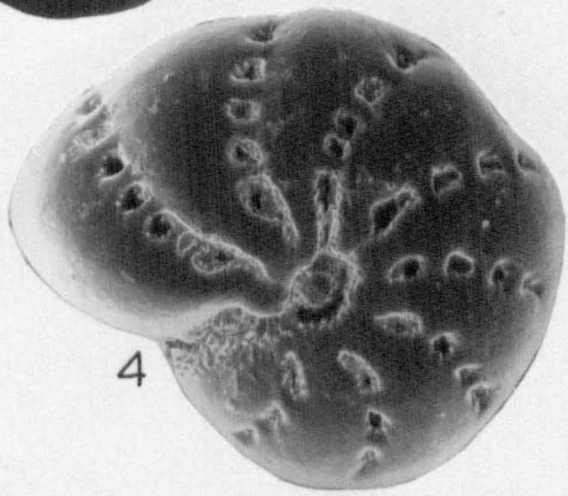
1b

1c

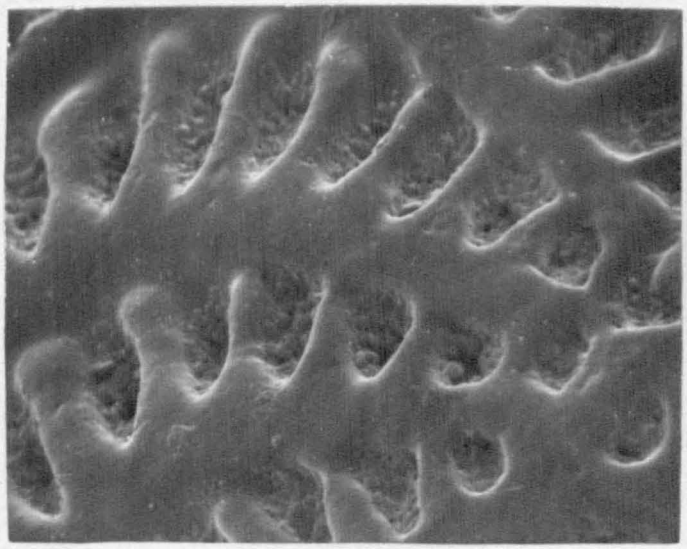




2



4



3a

3b

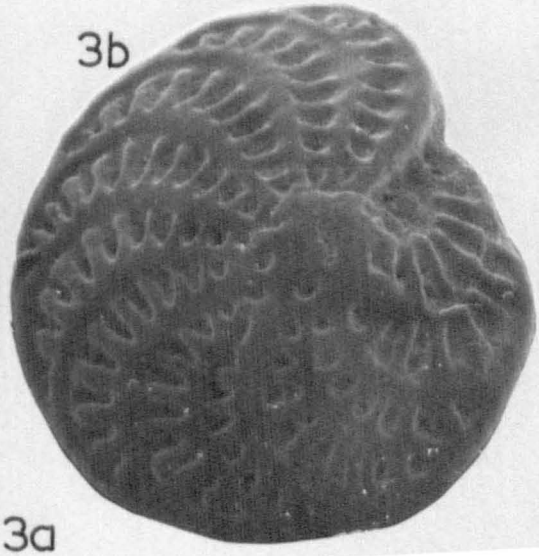


PLATE 16

Fig. 1a *Elphidium* c.f. *E. flexuosum* (d'Orbigny), juvenile specimen, x 320.

1b " " " , adult, x 125.

2 *E. incertum* (Williamson), x 210.

3 *E. lidoense* Cushman, x 230.

4 *E. oceanense* (d'Orbigny), x 200.

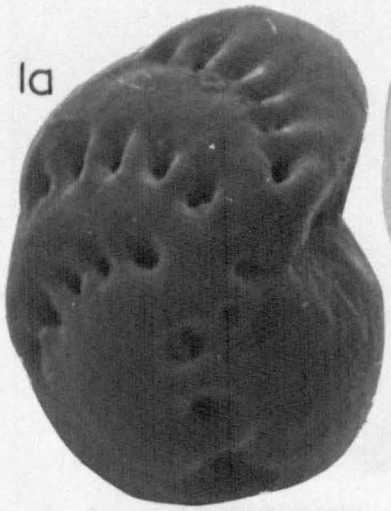
5 *E.* cf. *E. schmittii* Cushman and Wickenden, x 400.

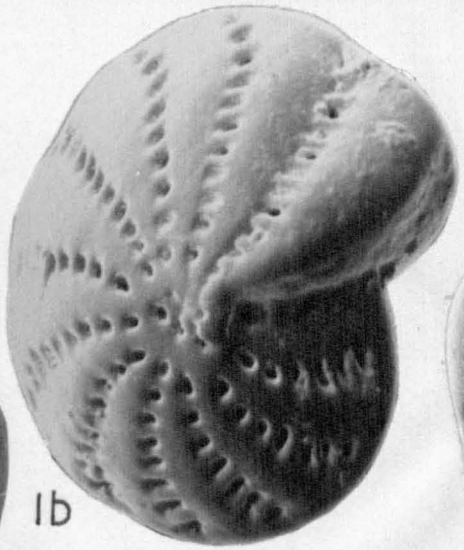
6 *E. selseyensis* (Heron - Allen and Earland), x 195.

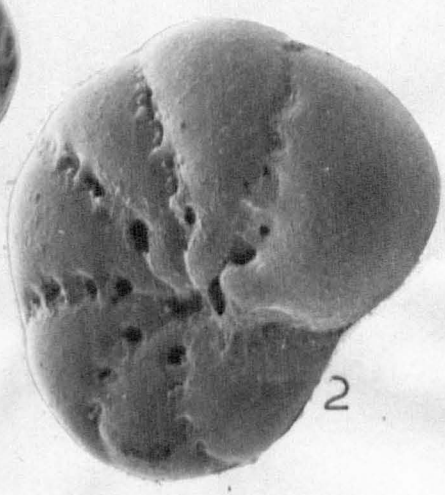
7 *E.* sp. 1, x 270.

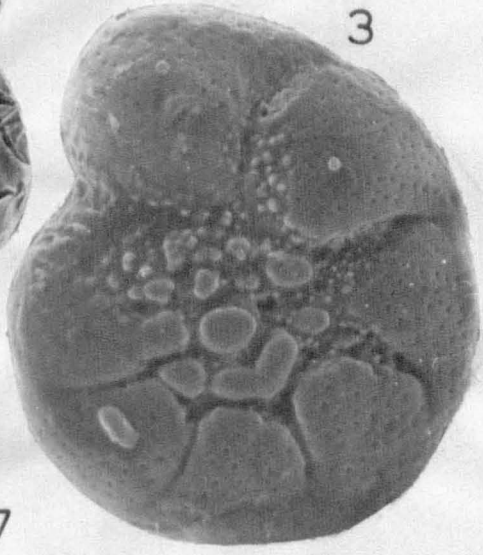
8 *E.* sp. 2, x 265.

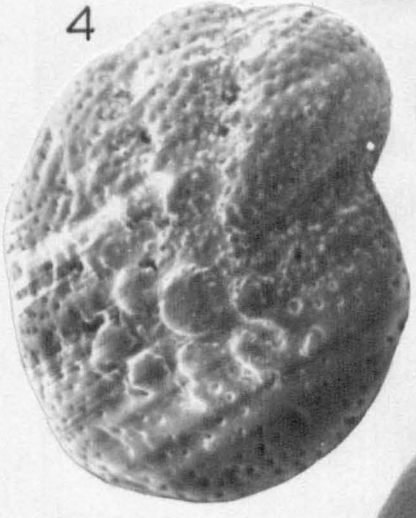
PLATE 16


1a


1b

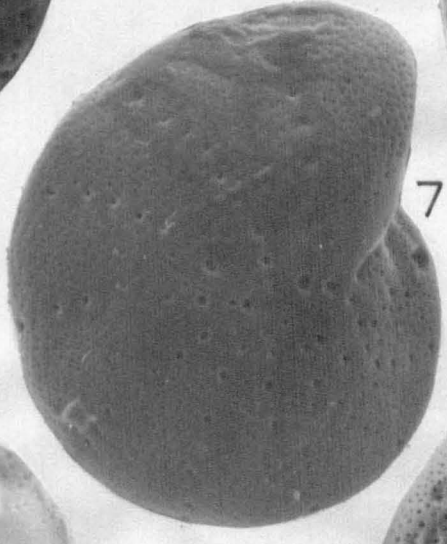

2


3


4


5


6


7

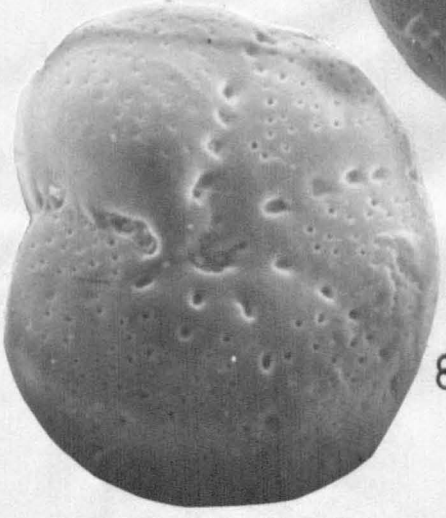

8

PLATE 17

Fig. 1 *Protelphidium anglicum* Murray, x 275.

2a *Globigerina bulloides* d'Orbigny, x 335.

2b " " " , ventro - lateral view, x 260.

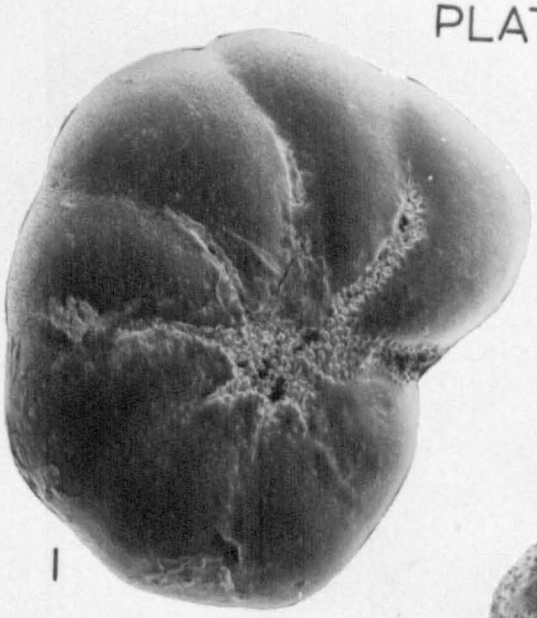
3 *G. inflata* d'Orbigny, x 250.

4 *G. pachyderma* (Ehrenberg), x 400.

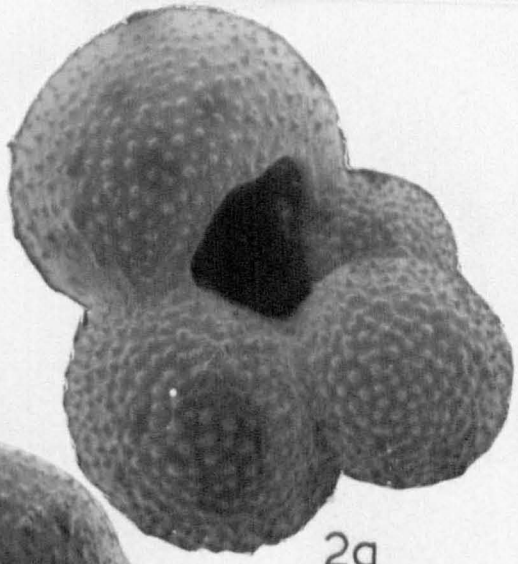
5a *G. quinqueloba* Natland, x 330.

5b " " , opposite view, x 325.

PLATE 17

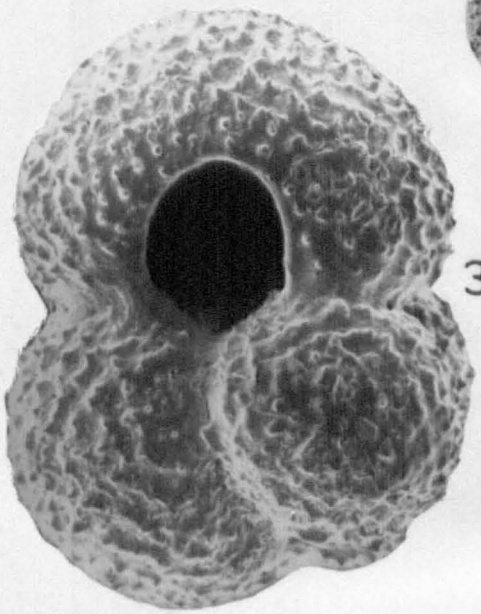


1

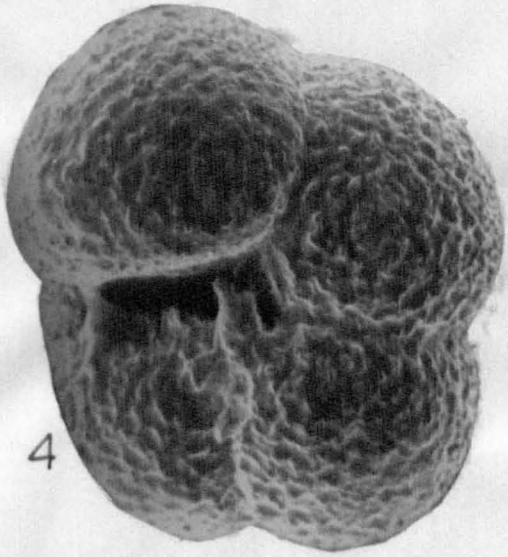


2a

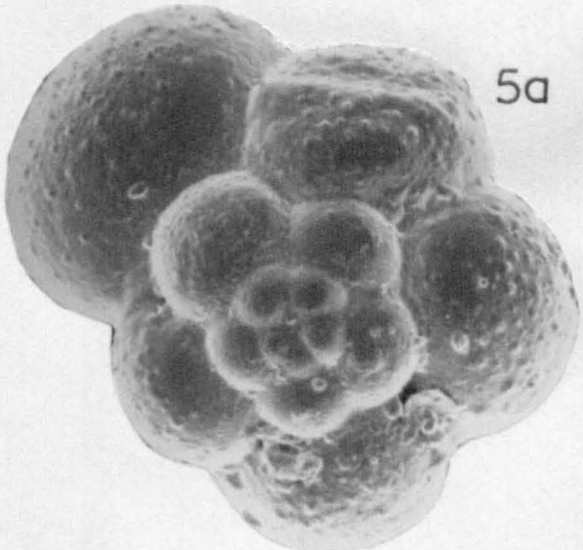
2b



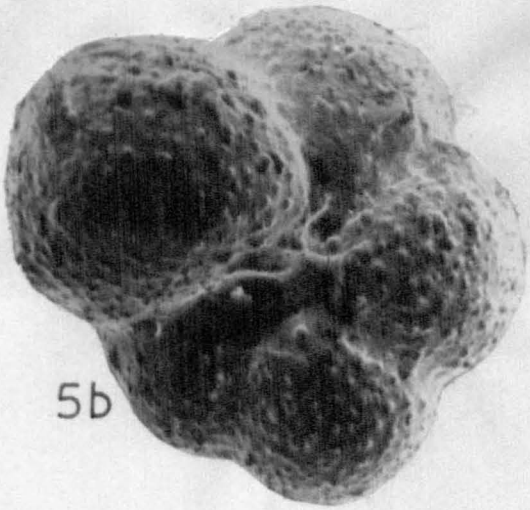
3



4



5a



5b

PLATE 18

Fig. 1a *Eponides granulata* di Napoli Alliata, ventral view, x 205.

1b " " " " , dorsal view, x 205.

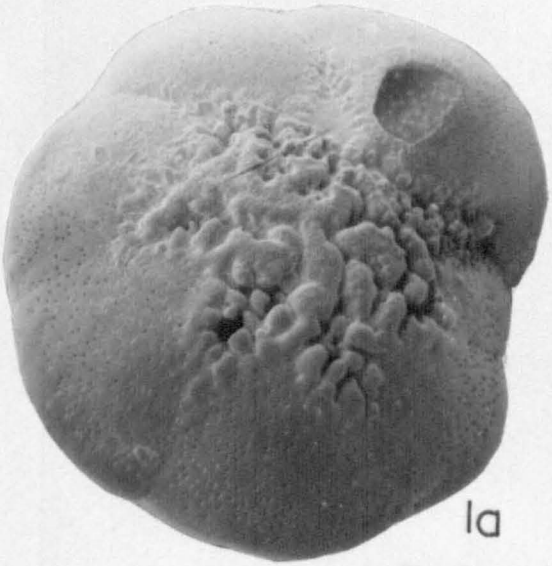
2a *Poroeponides lateralis* (Terquem), ventral view, x 110.

2b " " " , dorsal view, x 110.

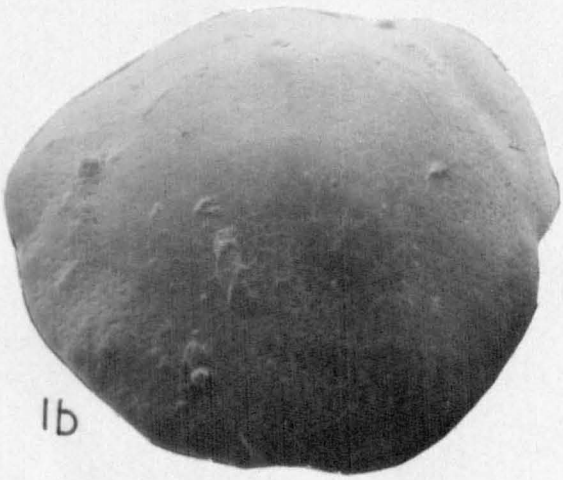
3 *Planulina ariminensis* d'Orbigny, x 235.

4 *Cibicides* c.f. *C. bradyi* Tolmachoff, x 210.

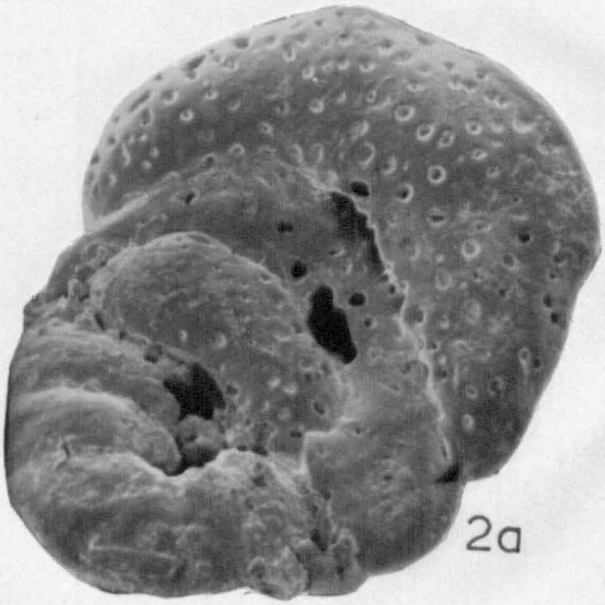
PLATE 18



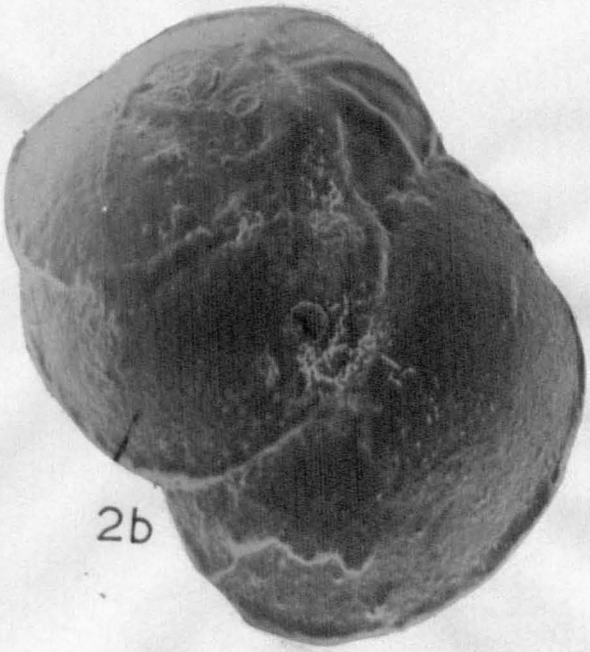
1a



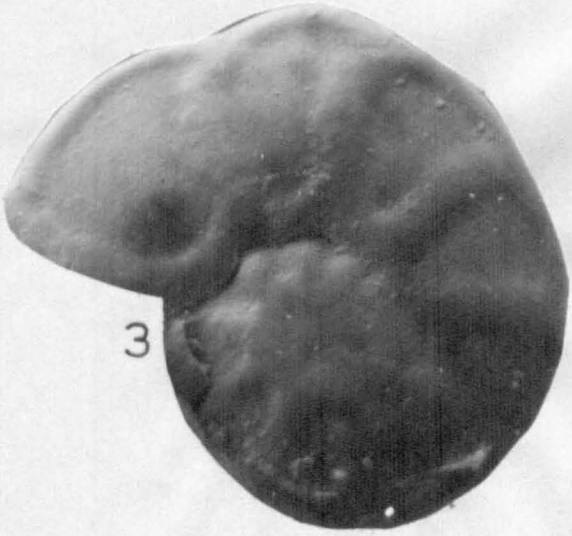
1b



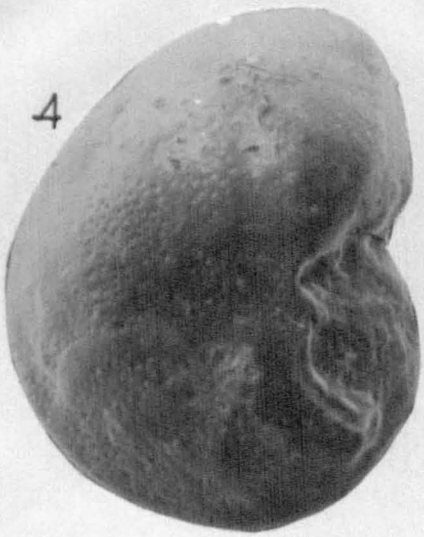
2a



2b



3



4

PLATE 19

Fig. 1a *Cibicides lobatulus* (Walker and Jacob), ventral view, x 240.

1b " " " " , dorsal view, x 240.

2 *Planorbulina mediterranensis* d'Orbigny, x 200.

3 *Fursenkoina* c.f. *F. complanata* (Egger), x 220.

4 *F. schreibersiana* (Czjzek), x 230.

5 *F.* sp., x 150.

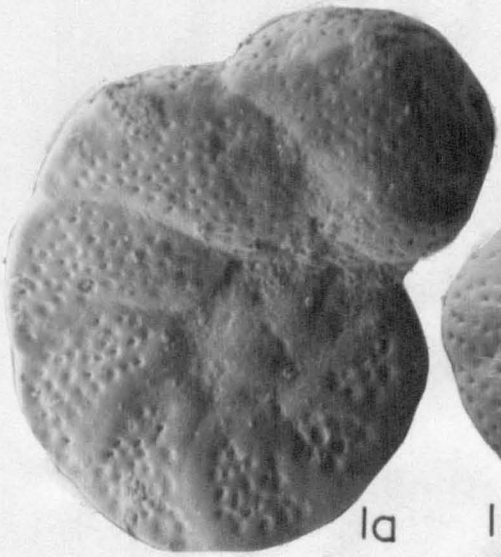
6 *Delosina complexa* (Sidebottom), x 145.

7 *Cassidulina laevigata* d'Orbigny, x 195.

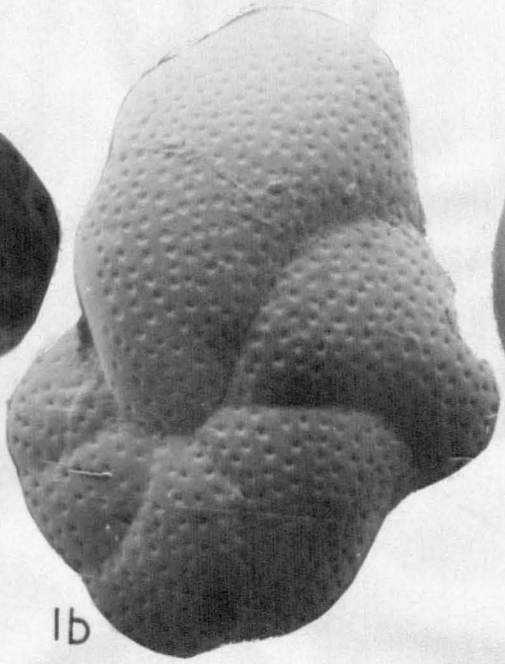
8 *C.* c.f. *C. crassa* d'Orbigny, x 420.

9 *Globocassidulina* sp., x 250.

PLATE 19

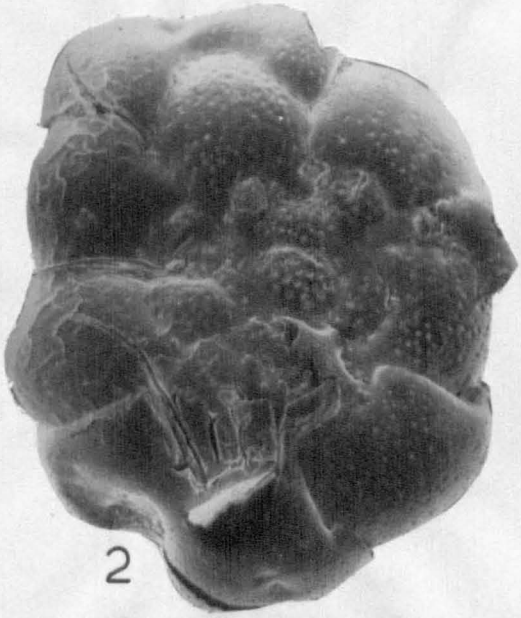


1a



1b

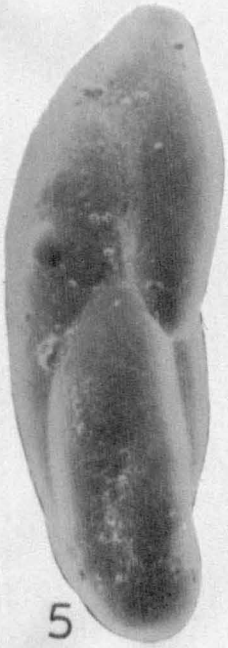
6



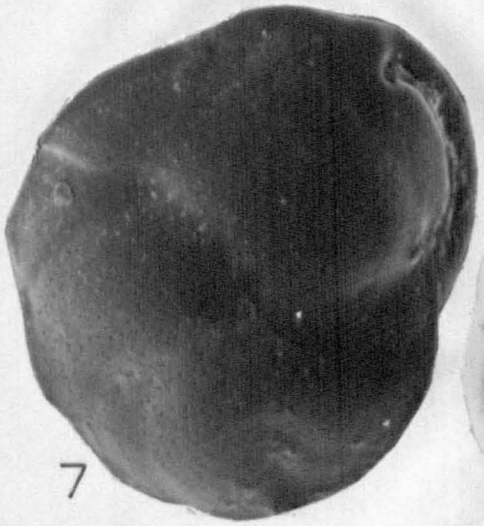
2

3

4

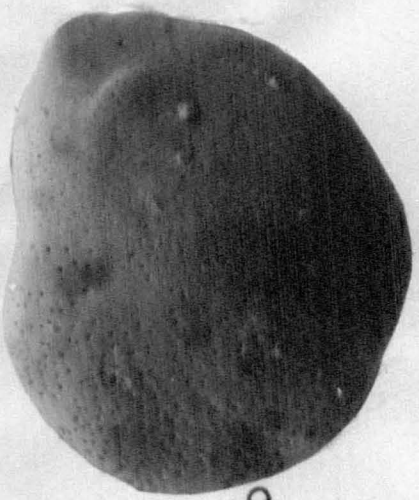


5



7

8



9

PLATE 20

Fig. 1a *Nonion asterizans* (Fichtel and Moll), detail of sutural apertures, x 400.

1b " " " " , x 165.

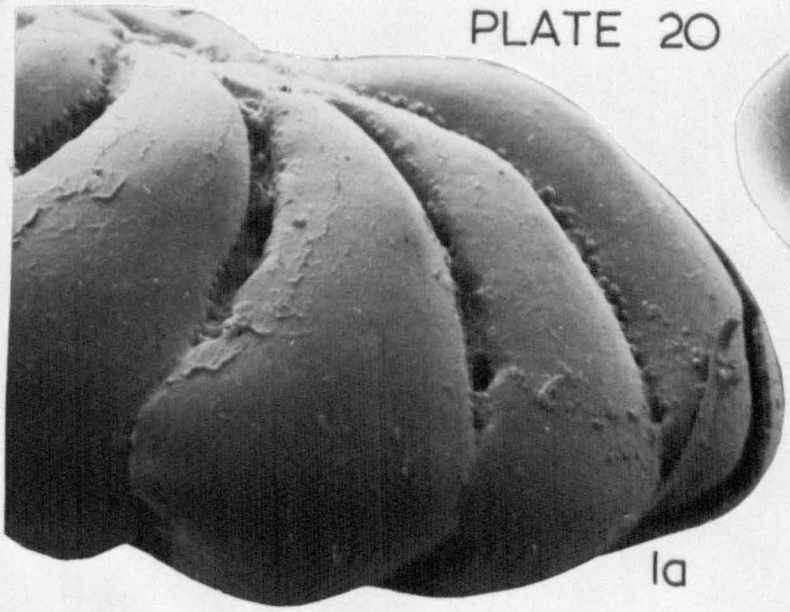
2 *N. depressulus* (Walker and Jacob), x 340.

3 *N.* c.f. *N. germanicum* (Ehrenberg), x 305.

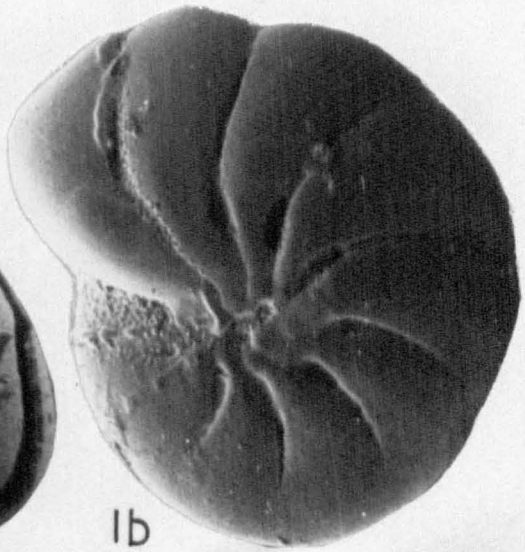
4 *N. laevigatum* (d'Orbigny), x 430.

5 *N. matagordanum* Kornfeld, x 320.

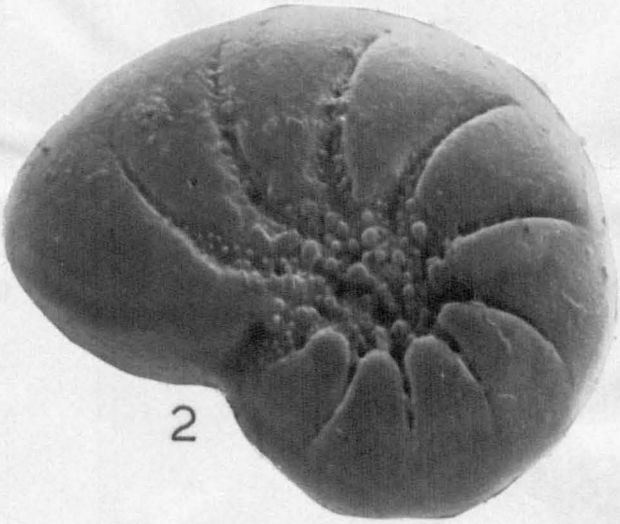
PLATE 20



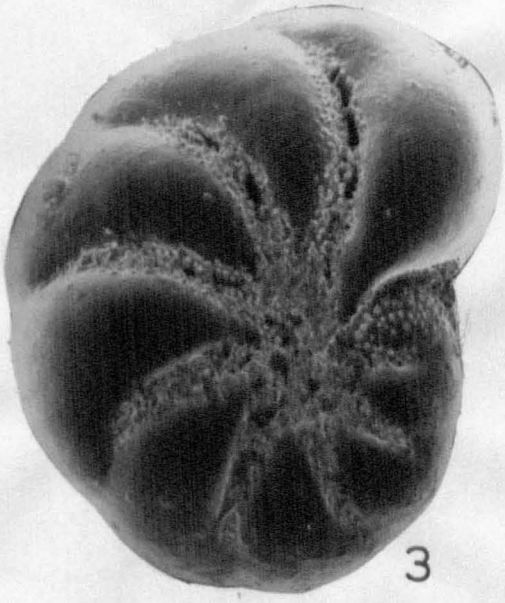
1a



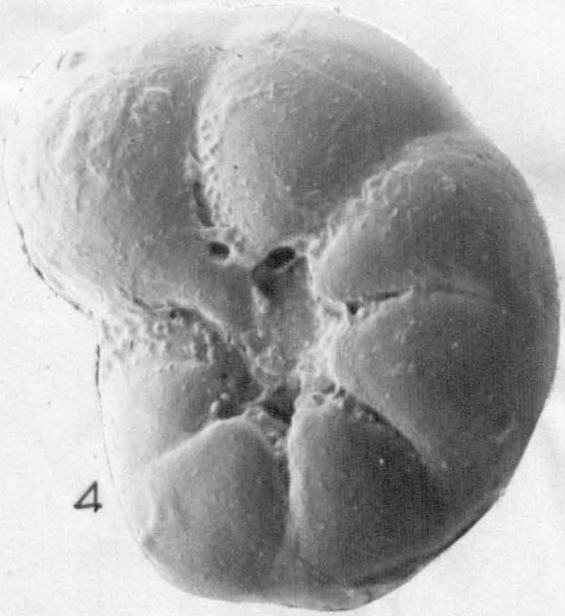
1b



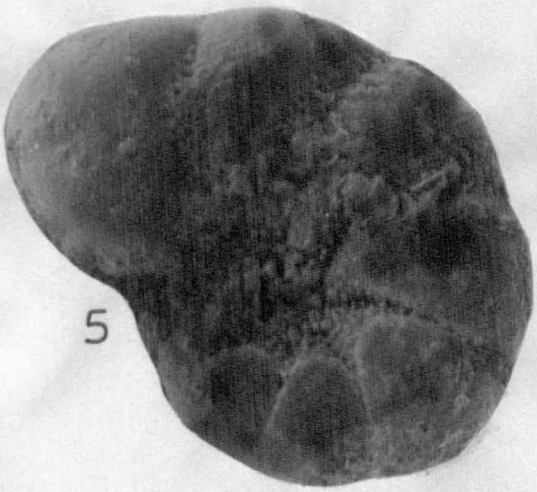
2



3



4



5

PLATE 21

Fig. 1 *Florilus scaphus* (Fichtel and Moll), x 150.

2 *F.* c.f. *F. japonicum* (Asano), x 335.

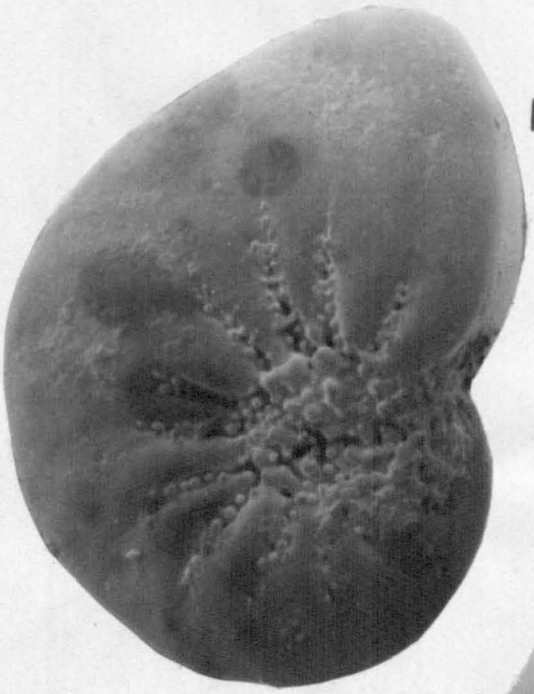
3 *Nonionella atlantica* Cushman, x 195.

4a *N. opima* Cushman, ventral view, x 210.

4b " " , dorsal view, x 210.

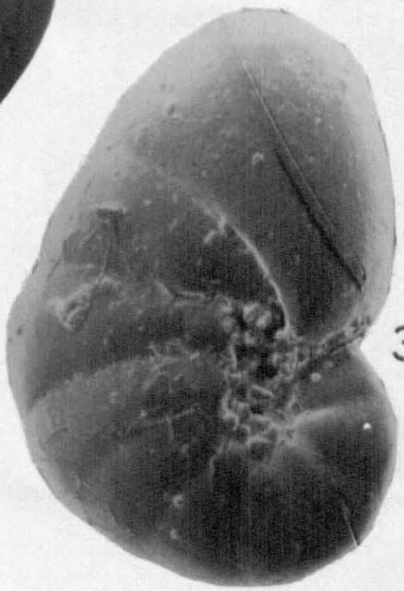
4c " " , dorso - lateral view, x 210.

PLATE 21

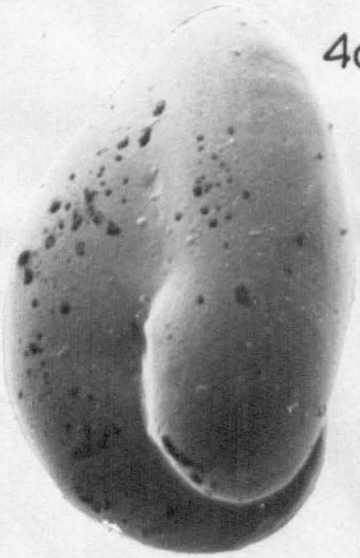


1

2

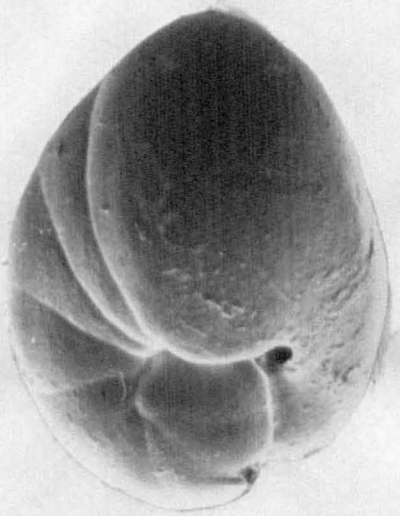


3



4a

4b



4c

PLATE 22

Fig. 1a *Gyroidina* c.f. *G. umbonata* (Silvestri), dorsal view, x 300.

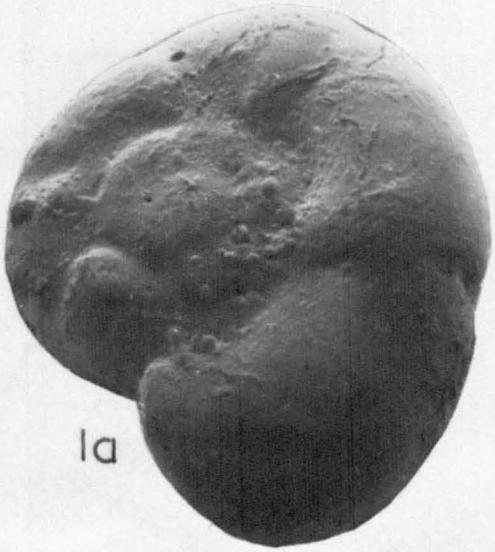
1b " " " , dorso - lateral view, x 380.

1c " " " , ventral view, x 350.

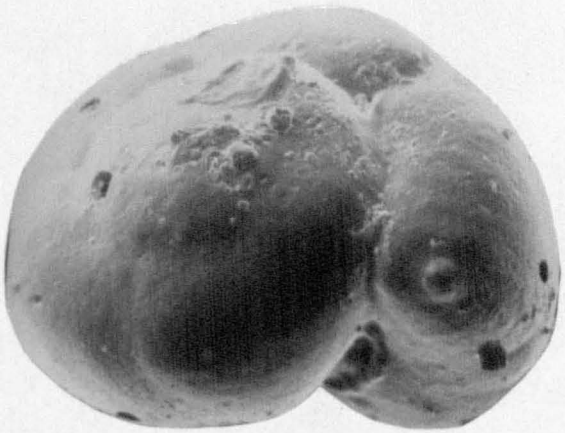
2 *Melonis pompilioides* (Fichtel and Moll), x 210.

3 *Robertina arctica* d'Orbigny emend. Hoglund, x 310.

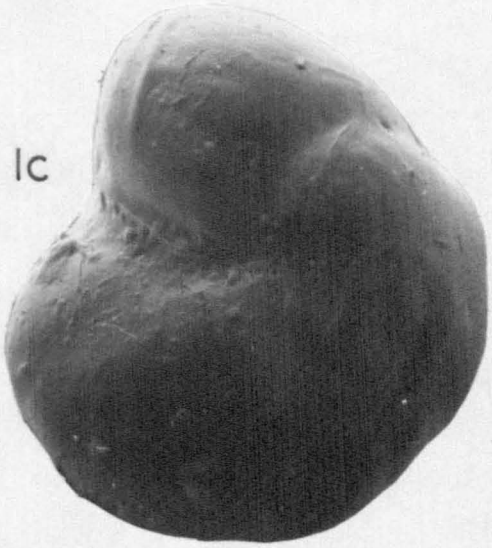
PLATE 22



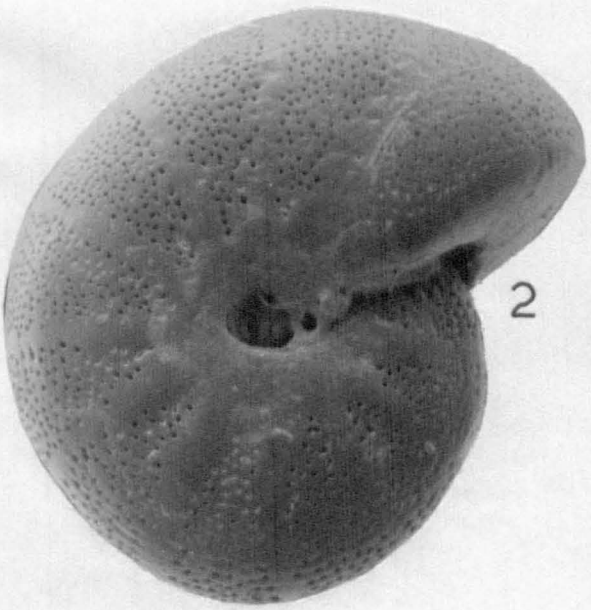
1a



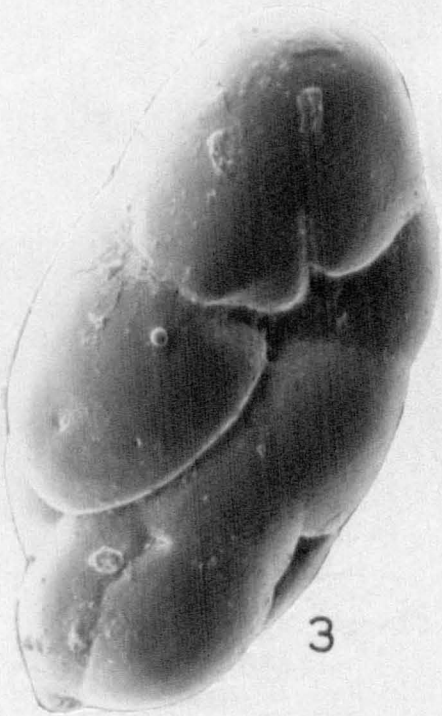
1b



1c



2



3

APPENDIX 2b Foraminiferal data: living populations, relative abundance (%).

| | SP 2 | 4 | 5 | 7 | 8 | 9 | 10 | 11 | 12 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | SV 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 12A | 13 | 14 | 15 | 16 | 17 | 17A | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | S 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 19A | 20 | 21 | 22 | 23 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | BRAZOS CORES 3/1 | 5/3 | 14/6 |
|---|---|---

APPENDIX 2c Foraminiferal data: dead populations and cores, relative abundance (%).

| | SP 2 | 5 | 9 | 10 | 12 | 14 | 15 | 16 | 18 | 19 | 23 | 24 | 26 | 28 | 30 | 31 | 33 | 36 | 38 | 40 | 42 | 46 | 50 | SU 1 | 2 | 5 | 6 | 8 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 30 | 32 | 34 | 37 | 39 | 41 | 42 | 44 | 48 | S 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 27 | 31 | CORES → C 2 | C3/1 | C3/2 | C6/1 | C6/2 | C8/1 | C8/2 | C8/3 | C8/4 | C8/5 | C9/1 | C9/2 | C9/3 | C10/1 | C10/2 | C10/3 | C10/4 | C10/5 |
|---|---|---

APPENDIX 2a Foraminiferal data: living populations, absolute abundance.

Species	SP 2	4	5	7	8	9	10	11	12	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Psammosphaera bowmani						1											1						1						2		2				7						1					
Saccammina atlantica	2			1					12					2																			1													
S. cognitina			1	3	3	34		9	2					20	4						4	31	33	13											1	1										
S. diffluciformis	8							1			1			8	9								2	2																						
S. lagunula				2	1	3		12	2				6													3																				
Reophax cylindrica	2				1								1																																
R. dentaliniformis														1	1																														
R. cf. R. fusiformis							1							7							4	6	5							4	4	1	2	1											
R. monliformis																																													
R. nana																													2						1	2									
R. recurvirris						3		1	4					1								4	2	2					2					5	3										
R. scotti															2						2															1	4	2								
R. subfusiformis	17			1							8	1	2									8	12	11																					
Nouria polymorphinoides																																	6	5											
Hyalinonetrion fusca			1				1						2																																
Haplophragmoides canariensis			6	15		6	1	11	8				2	2	1		1			2	5	2	3		9	3	13		2	3	6	3	1	3											
Ammobaculites cf. A. arenaria																						3			3																				
Ammotium cf. A. radium																																													
Textularia calva			1	2	3	4		9	2		1	4	3									8	7	3	7					9	3	7	3												
T. tenuissima			7	5	3	2		2	1	1					3	5					3	5							4	3		1	1	1	7	3								
T. sp.																																													
Trochammina cf. T. advena								5	1					1	8	6					1		1			1	1		2	1															
T. inflata																																													
T. lobata						1	3	2													3													23	8	2		1		3					
T. sp.			2																										3						3	2			1		5				
Ammosphaeroidina sphaeroidinif	7	2	2	5	11	29		10	3	1		1	7	3	8	3				4	1	17	16			4		1	2			7					3	3	7	8						
Jadammina macrescens																																													
Eggerella scabra	8		4	2	3	21			6	1		2	3	2	5	1				6	1	7	6	3		1	1	8				1	1	1	9	2									
E. advena			1																					1	2		1		2																
Clavulina obscura			1	4		3		13	3	1				1		5	6		1	1		1		1	4				4	4	5			3	5	2									
Cyclogyra incerta					1							1		21									2	13	1	25	4	2	1	5	9	9		10	28		4	3							
Vertebralina striata																																													
Quinqueloculina depressa						2				1		1																							4				2						
Q. laevigata		5			1		4	2	1					2											2	3		2		2															
Q. longirostra		5	5		2		5							2			2																												
Q. rugosa				1											8	2																				4	1								
Q. schlumbergeri		12		2		12	11	15	20	7		3	1	5	30	25	80	23	16	27	15	2			1	1	7	8	34	3		2	2	6	40	62			9	30	21	17	7	3	14	1
Q. seminulum			1	11				2				1		4	3			1	2					3					10			1	2			1	1								
Q. sp.																																													
Pyrgo inornata													2																																	
Sigmilina secans																													3																	
Triloculina dubia		1				1	1								3	1	1						1						1		1					2									
T. marioni	1	1	1																																										
T. rotunda										1																			8							3	3								
T. sp.		1	2			2	8	10	1	1				2	28	3	2		3	5	2	1			1	3	9	1		1		2	2	35	12		3	18	2	1			6	4	1
Cushicoryna scalaris	1																																												
Lagena clavata	1			1			2						1								1	1		1					2	1		2												
L. c.f. L. semistriata					1		4						1	1	4											1																		
L. substriata					2								1								1	2		1					2															
L. sulcata	2		2	2				1													1								3															
L. tenuis						1																																							
L. vulgaris																					1			1					2															
Fissurina lucida		1								1											2	2		4																				
F. sp.			1																											1	2		1	2										
Pullenella elegantissima			3			1				1	1										1		2	1	2	6	2	12	1		3		3	3	8	5	6	18	3	2		1	2		
Reliyina pseudoplicata																														4	4		1			5	9	4	26	3	2	4	4	1		
Trizalina c.f. T. semeriensis					13		2				1	1										2	12	1									1												
R. pseudovuncata	9	15	3	44	23	66	2	34	14	4	1	10	11	36	23	26		3	1	44	113	99	45	13	7	14	16	38	82	5	18	28	8	24	21	3	2	2	8	6	1	1	1	4	49	13
R. spathulata			2		7	3						2	4	6	1						3	7	3	1																					
R. striatula					3	1		1		1		2		3	1					2	1				4				41	3	6	6	6	11		22	6	32	64	17	10	10	8	12	4
Reliyina oculosa	12	10	7	27	9	20		14	8	1		23	20	28	20	10		2	14	31	37	15	49	6	20	6	13	5	2	11	12	13	8	2				1	4		1	1	47	2
R. elongata	3		2	6	5	1		6	3			1		10	1	4					3		7	4	4																		5	
R. gibba	2			7	1	5		2				14	3	16	6	5		1	9	24	80	4		1	1	2		14	5	2	14	4		1										19
R. nitidula																																													
R. nitidulinoides